metal
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Metal Progress

May 1958 . . . Volume 73, No. 5

Cover by ROBERT L. SCIPIONE,
Student at Cleveland Institute of Art

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When molten aluminum alloys – for example 8% iron – are atomized, the fine powder can be compacted and extruded into metal parts with superior strength and structure stability at 400 to 800° F. (H10f, Q-general, 2-62; Al)*

Coming: Better Thermenol Alloys, by W. J. Buehler and C. G. Dalrymple 78
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A Look at High-Frequency Resistance Welding, by Wallace C. Rudd 82
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Electric Furnace Refractories, by E. C. Wright 87
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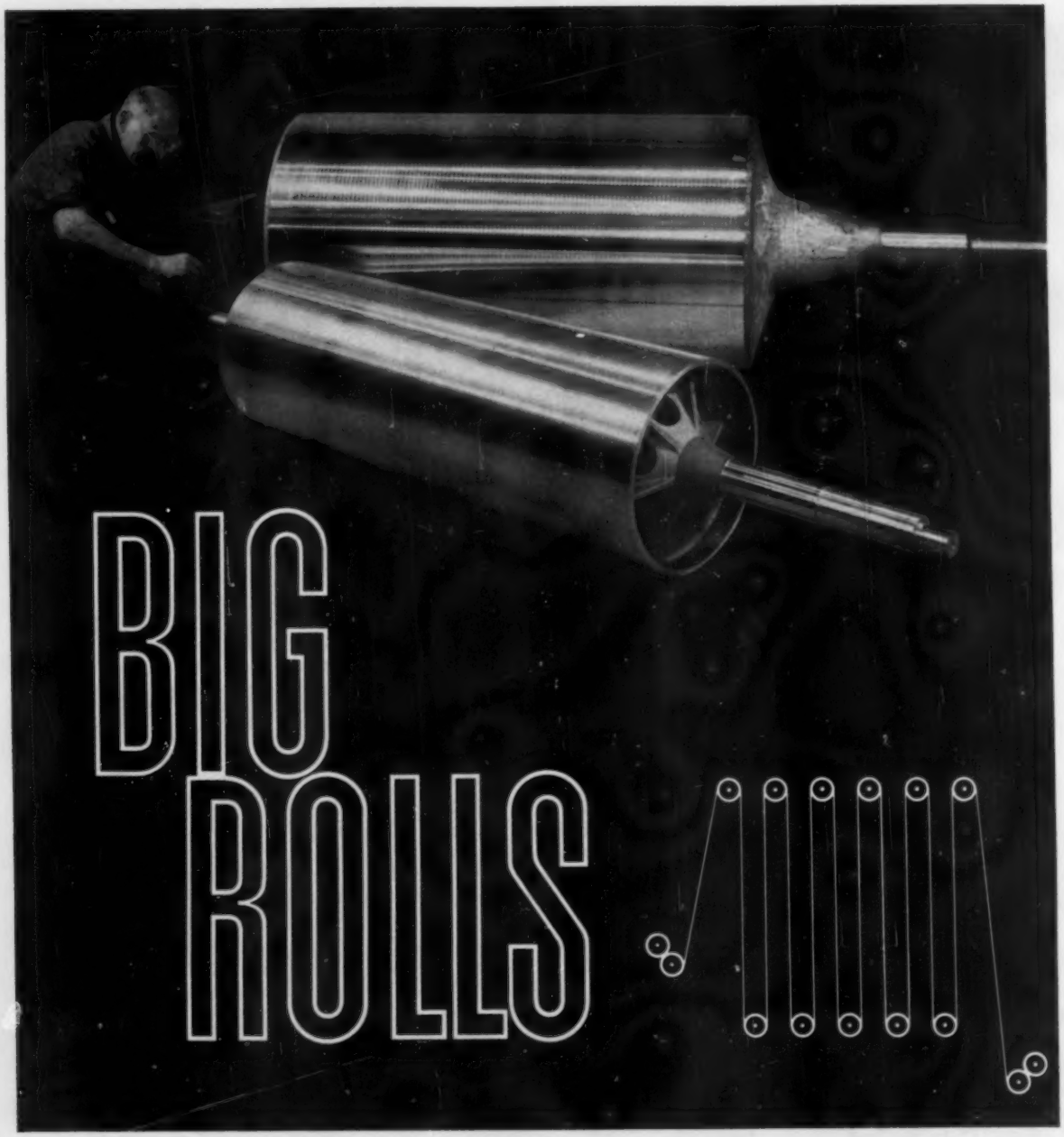

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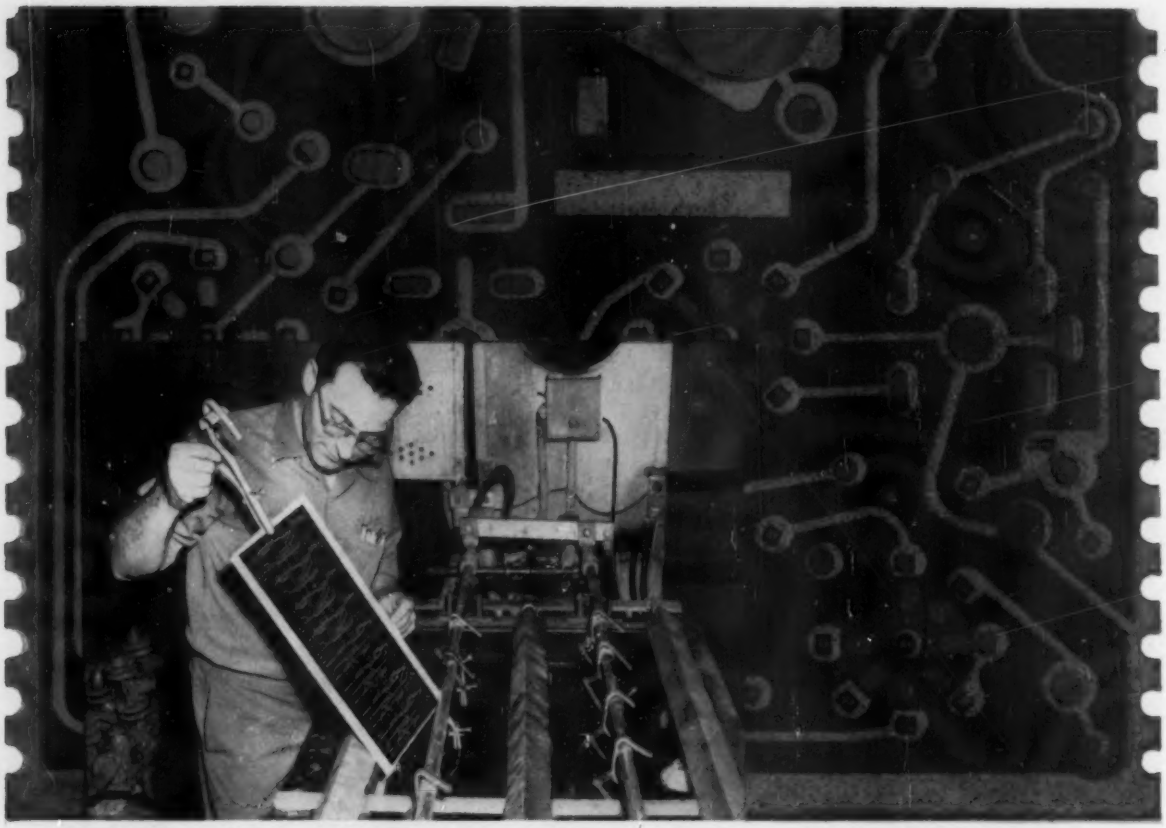

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As I was saying...

A FEW MONTHS have passed since the overseas conferees to the Second World Metallurgical Congress have returned to their homes and it seems only natural that occasionally they recall the event and are moved to drop me a line. It would do all ASMers a world of good if you might have an opportunity to read these letters and recognize and realize for yourselves the sincerity and the friendly sentiment extended to the Society, the American conferees and the staff. Here are just a few expressions taken from the hundred or so letters that have been received:

Interesting time. . . . A great wealth of interesting experiences. . . . Very impressed. . . . Many fine people. . . . Very friendly and helpful. . . . A good impression of the living standards and customs. . . . Many interesting lectures. . . . A splendid opportunity to exchange professional opinions. . . . Glad to have an opportunity to observe the mechanics of the wonderful Congress. . . . The certificate will remain a memento. . . . The Congress was a great success not only from a technical standpoint but from the human aspect. . . . I thank you from my whole heart. . . . Everyone cooperated in the true spirit of friendship. . . . Contacts were extremely stimulating and refreshing. . . . The organization of the Congress was indeed perfect. . . . Deeply impressed by hospitality of American friends. . . . Anxious to see Sunnimoor Farm with no snow. . . . Very memorable occasion socially. . . . Great value technically. . . . A credit to your organization. . . . A great personal achievement. . . . The tour has been of great benefit to us. . . . A very fruitful visit. . . . It really was a mighty gathering. . . . The Congress was interesting and inspiring. . . . It will be remembered for a long time. . . . The spirit of neighborliness and the friendly manner demonstrates A.S.M. members as true representatives in helping bring about the interchange of technical knowledge. . . . Correspondence already initiated with newly made friends. . . . Time was indeed too short. . . . The organization ran smoothly from the beginning. . . . I think it was your good wife who introduced me to rum with tea in the House of Friendship. . . . These events are unforgettable. . . . The contacts are world rewarding. . . . Feel happy about all we have received through A.S.M. . . . The tour was excellent. . . . Congress most amazing. . . . The great Congress made our work successful and it broadened our knowledge and understanding. . . . The discussion of technical problems and the spirit of fellowship should make the need for wars most difficult. . . . It was instructive, beneficial, and above all friendly . . . etc.

It has been my pleasure to have met hundreds of the American counterparts, and they all express the same thought that the Second W.M.C. was one of the high-water marks of their scientific careers. So, having heard both sides of this pleasant exchange, I'm convinced that we may both rest the case with firm assurance that the friendships started and to be continued will contribute greatly toward the "Peace on Earth" we all so devoutly desire.

Cordially yours,

Bill

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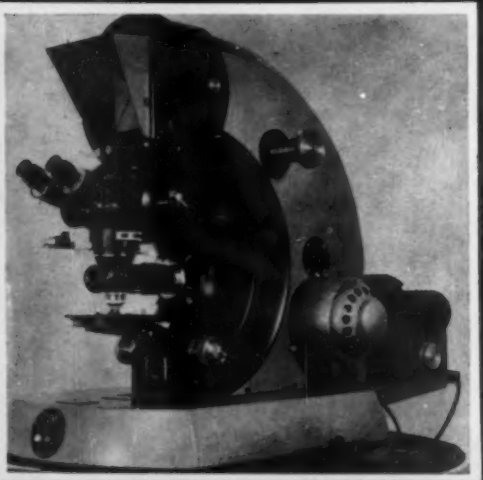

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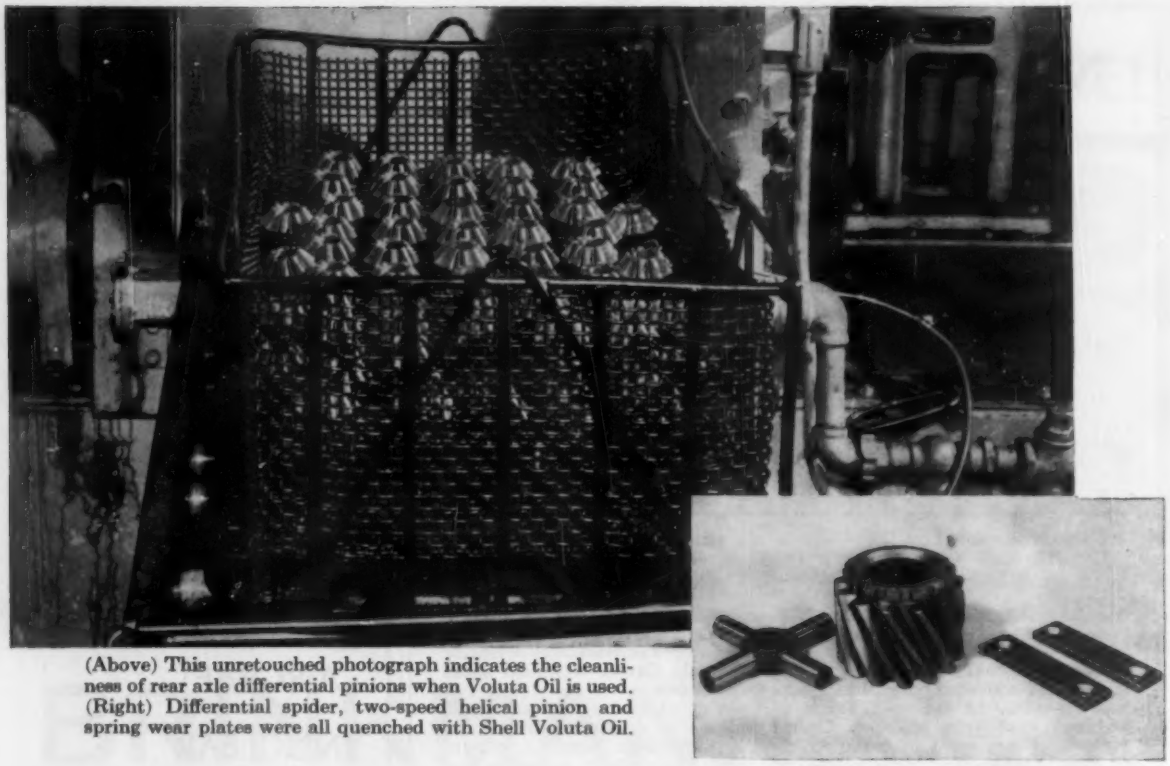

(Above) This unretouched photograph indicates the cleanliness of rear axle differential pinions when Voluta Oil is used. (Right) Differential spider, two-speed helical pinion and spring wear plates were all quenched with Shell Voluta Oil.

Here's a stable, high-speed quenching oil that minimizes work distortion

There has long been an urgent need for a uniformly stable quenching oil that would perform satisfactorily with minimum distortion of the workpiece. During the quenching operation, fluid deterioration can occur, causing sludge and acid formations which in turn result in non-uniform physical characteristics of quenched parts.

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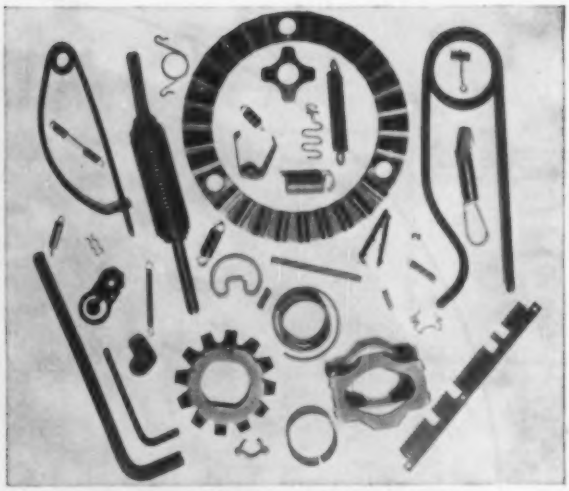
There are many applications that clearly demonstrate the efficiency and versatility of Voluta Oils.

One example relates to a leading producer of several thousand varieties of axle parts. With conventional quench oils, rejects were high due to unfavorable stress concentration and subsequent cracking. After changing to Voluta Oil, maximum uniformity was achieved because of Voluta's superior wetting-out properties and stable cooling rate. For heat-treating purposes, Voluta Oils proved stable at temperatures from 130° to 200° F. They also provided greater surface hardness, depth of hardness and uniformity.

A well-known manufacturer of automotive steering units was faced with a similar situation. Here the problem involved heat-treating low-carbon-steel parts as well as grey-iron castings. Although they were of widely varying materials, shapes and sizes, this company found that

Shaker hearth furnace automatically dumps parts into Shell Voluta Oil, then removes and drains them.



Over 35,000 prints of production items like these (quenched in Voluta Oil) are kept on file by one leading steel spring manufacturer.

Voluta Oil was far superior in all these ways: 1) longer life; 2) clean, scale-free parts; 3) wider range of quench temperatures; 4) no rejects due to distortion; 5) no sludge formation.

Still another case occurred during the manufacture of many thousands of different shaped springs. This company wanted to insure maximum elasticity of their springs, and to achieve this a 100 per cent martensitic structure had to be maintained. Tested in competition with several other quench oils, Shell Voluta Oil again proved superior because it resulted in the production of distortion-free springs, and allowed quicker drainage and minimum dragout loss.

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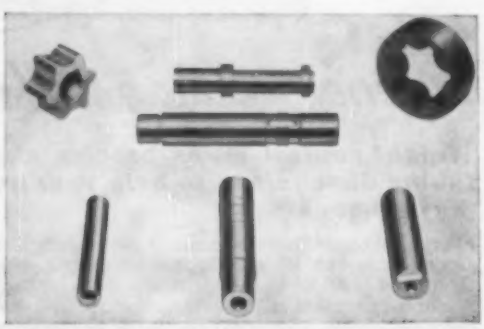

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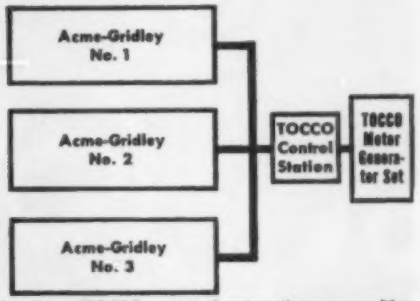

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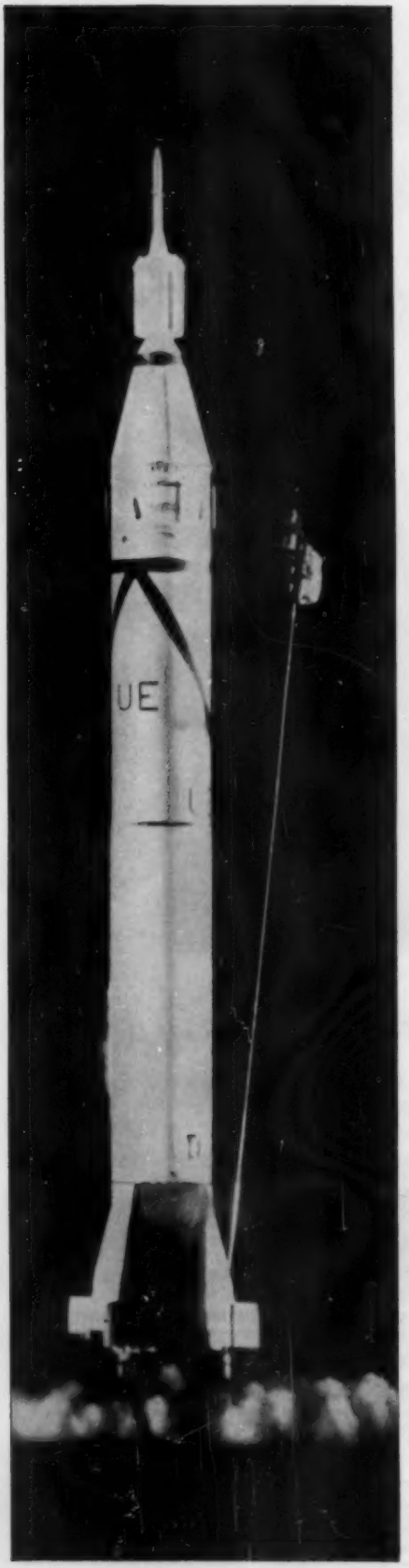

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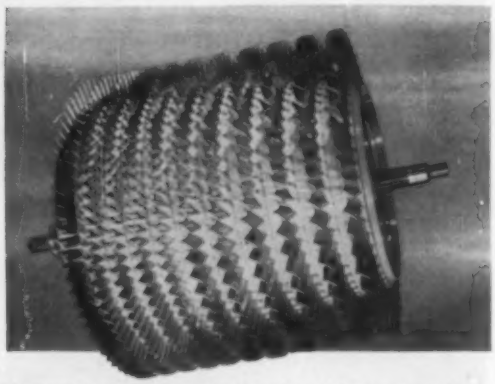
"Explorer I" is positioned on spin launcher. The satellite is spin-stabilized in much the same manner as a rifle bullet. Rotational spin of more than 700 RPM was started on the ground before the satellite was launched. In this Official U. S. Army photograph, the striped area at the top of the Explorer indicates the nose cone fabricated from Republic ENDURO Stainless Steel, Type 430.



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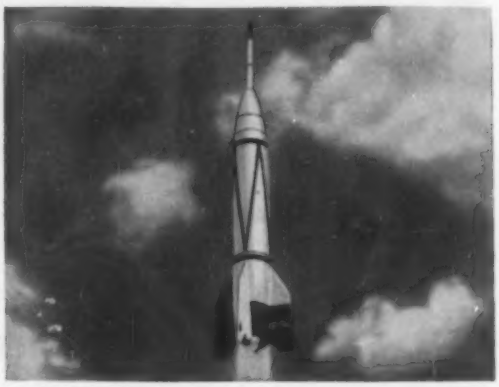

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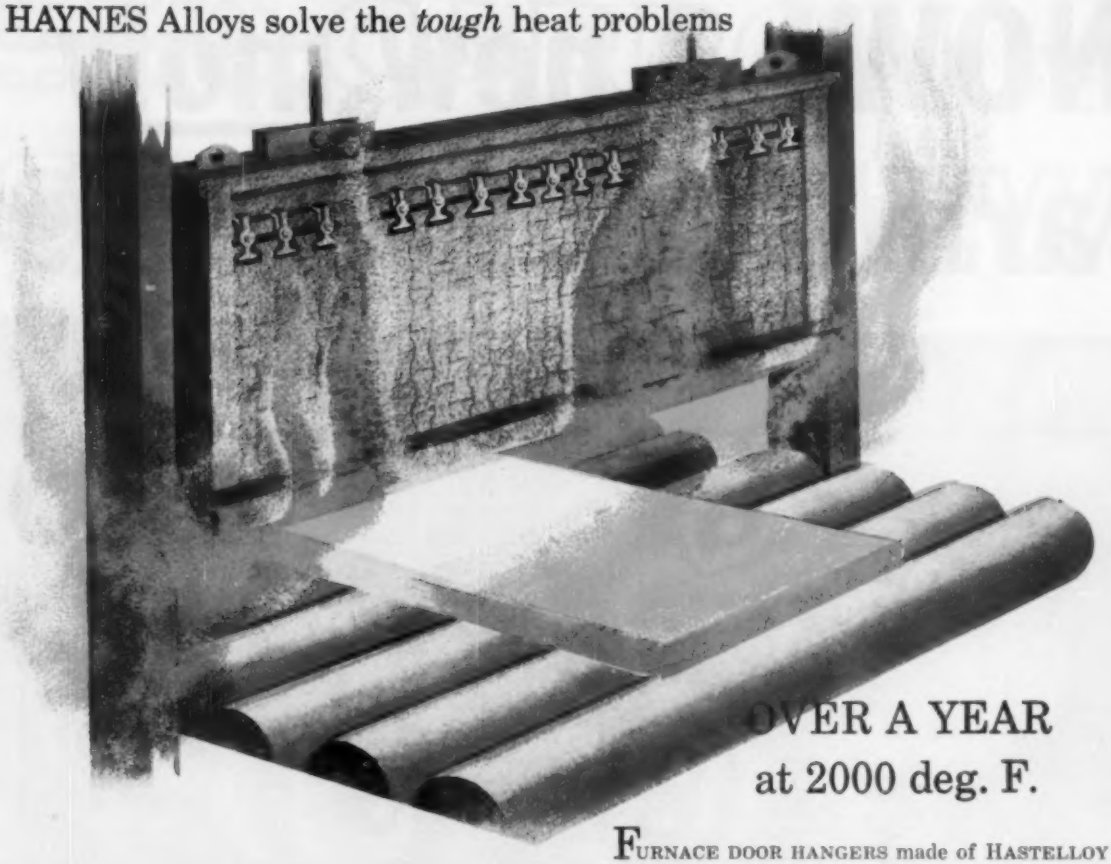

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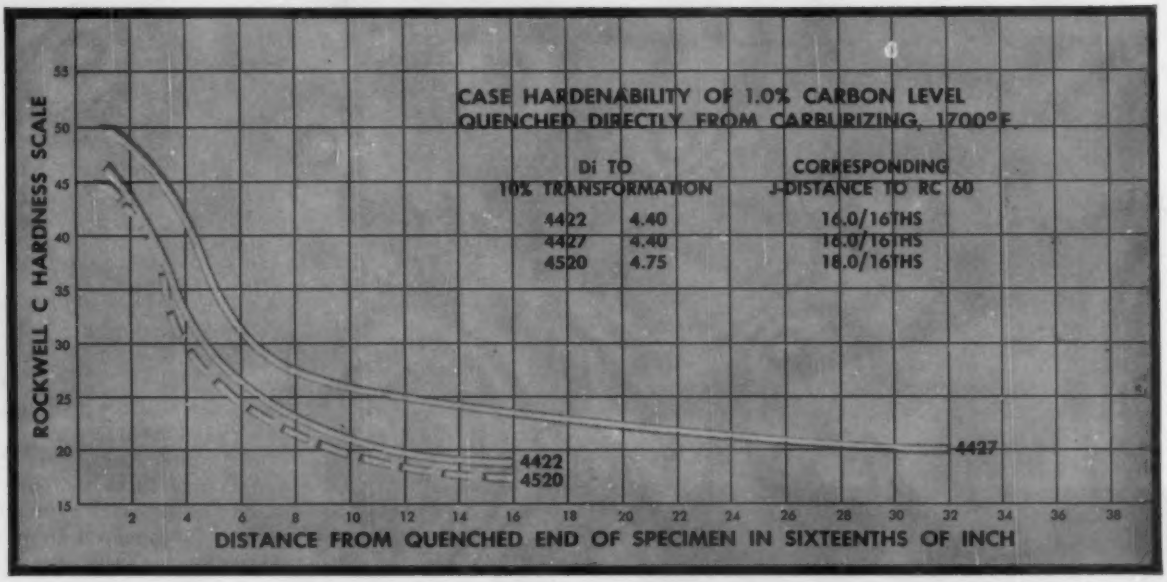

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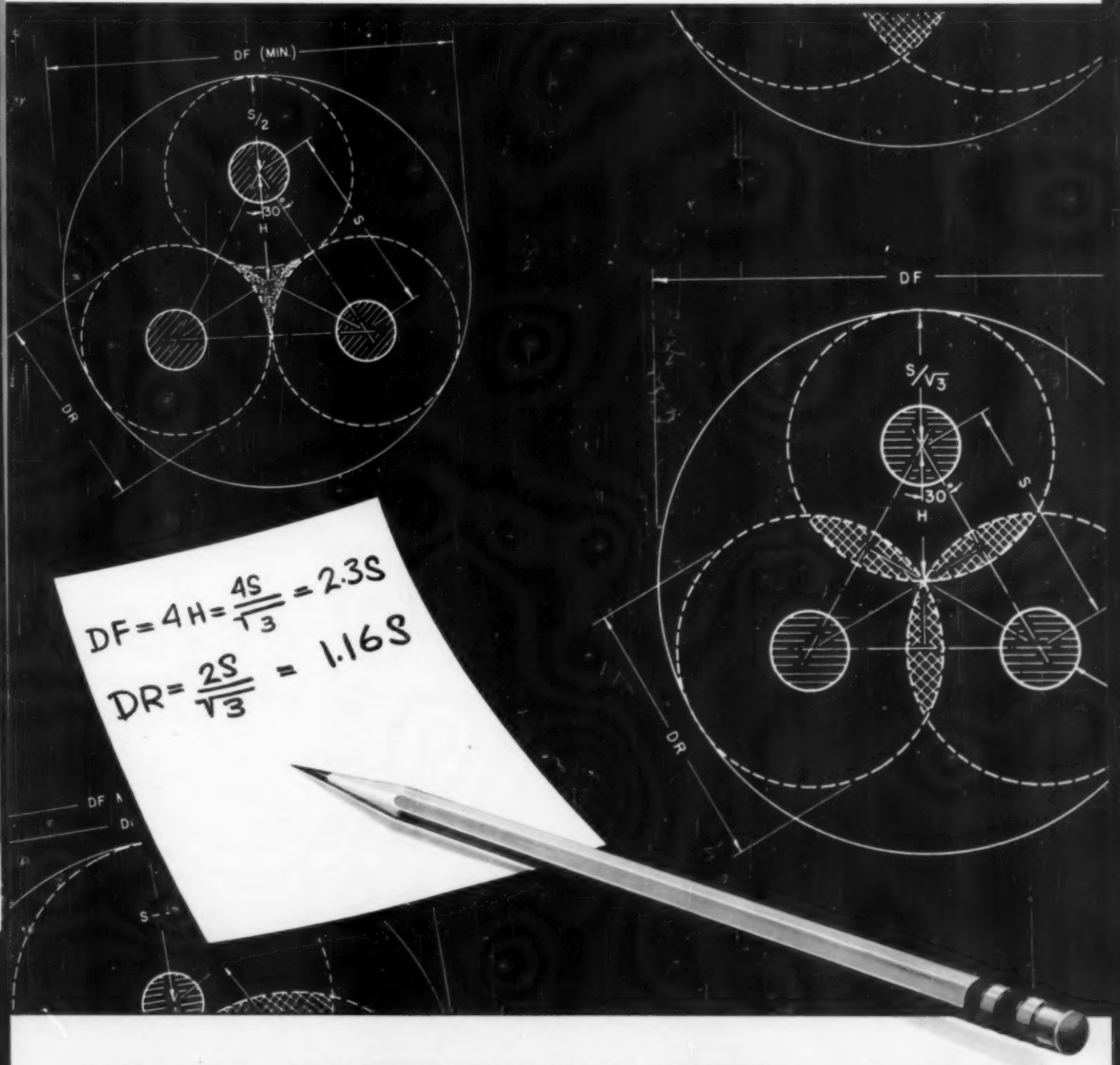


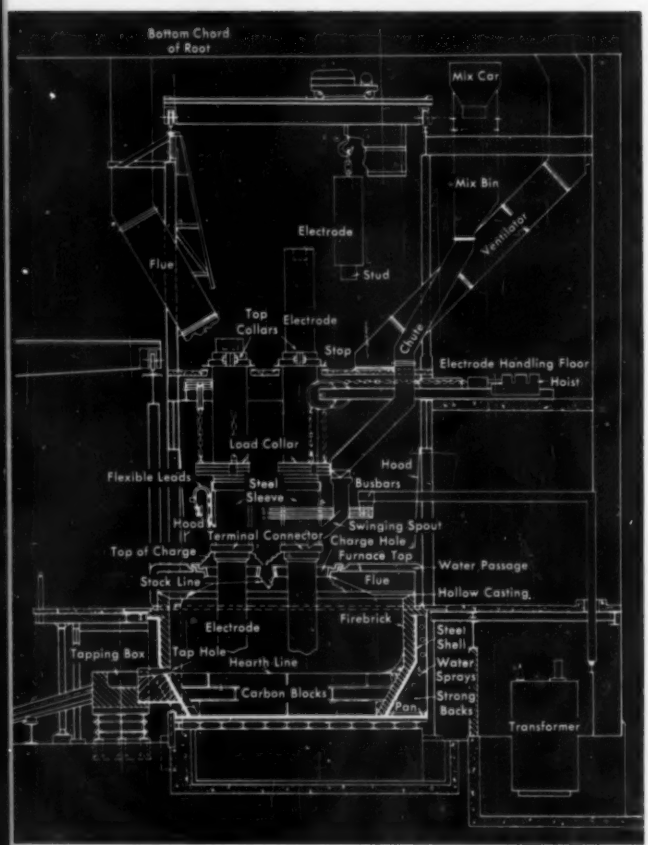
DESIGN AND CONSTRUCTION OF THE SUBMERGED ARC FURNACE

By W. M. KELLY, *Plant Metallurgist*, Niagara Works
Electro Metallurgical Company, Division of Union Carbide Corporation

DESIGN AND CONSTRUCTION OF THE SUBMERGED ARC FURNACE

. . . THE MODERN METALLURGICAL TOOL

By W. M. Kelly, *Plant Metallurgist*, Niagara Works
Electro Metallurgical Company, Division of Union Carbide Corporation



The Submerged Arc Furnace is a modern metallurgical tool for producing such industrial products as: Alloys, Calcium Carbide, Abrasives, Pig Iron, Phosphates and Titanium Dioxide. Shown is general cross section of typical ferroalloy furnace, auxiliaries and supporting structure.

Introduction

The first commercial submerged arc furnaces were placed in operation in the late 19th century. To a large degree their design has remained (for over a half century) a matter of arbitrary decision without formalization to ensure the most suitable metallurgical conditions. In general, this type of furnace has been designed almost entirely from the standpoint of the electrical universe it represents and several outstanding papers have been written concerning the electrical design of these heavy current furnace circuits.

The concept of a submerged arc furnace as a large, high temperature chemical vessel was little explored, and only trial and error information concerning furnace sizes, shapes, depths and electrode sizes was available. Gradually it was discovered that certain furnaces were suitable for given products, but eminently unsuitable for others. As the variety of alloys and materials produced by submerged arc smelting grew, the need arose for a system of predicting desirable furnace characteristics.

During the 1920's, F. V. Andreae developed the concept of electrode periphery resistance designated by the formula:

$$k = \frac{E \pi D}{I}$$

where k = electrode periphery resistance
E = electrode-to-ground voltage
I = current per electrode
D = electrode diameter in inches

This relationship, known as a "k" factor, was arrived at by observation of vast furnace data and noting that given smelting operations seemed to have a typical product of furnace resistance and electrode circumference. Although published in several papers by Mr. Andreae, it went almost unused for many years. Later, Mr. Andreae expanded on the concept by equating the heat generated by current flow in an electrode with the heat conducted from an electrode submerged in a high temperature zone and combined this equation with the electrode periphery resistance concept. It was concluded from this combination that the power density in an electrode must be constant if it is a valid assumption that electrode periphery resistance is a constant. Thus a beginning was made to a useful relationship between electrical conditions of a furnace and the metallurgical results.

During the early 1940's, after consultation with Mr. Andreae, the writer applied this concept to an accumulation of phosphorus furnace and ferroalloy furnace data for various products. In 1950, ranges of "k" factor were established for the principal submerged arc operations. This was based on the furnace data then available. From these data an attempt has been made to derive additional information relating to "k" factors and to associate this information with other design and operational considerations to formalize a suitable system for designing submerged arc furnaces with metallurgy in mind.

Electrical Conditions

Since submerged arc furnaces are *electric* furnaces, it is of prime design importance that there be a thorough understanding of the relation between electrical conditions and

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metallurgical results. Obviously a 10000 kw. furnace cannot be run at an indiscriminate voltage, and so the voltage-current relationship for a given load must be understood. The "k" factor concept provided this understanding for constant power densities.

Typical "k" factor values for the major submerged arc furnace operations are shown in Figure I. These ranges for a given product merely reflect the available data and were a first attempt to provide an orderly picture of the range of electrical conditions employed by these operations. In a few cases, such as 50% ferrosilicon, data were available for an exceptionally wide range of conditions. The figures shown represent the area where maximum performance results were obtained.

TYPICAL "K" FACTORS FOR SUBMERGED ARC OPERATIONS

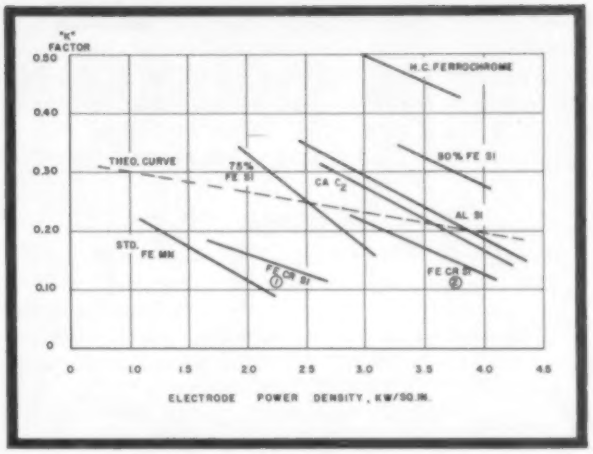
PRODUCT	"K" FACTOR
PHOSPHORUS	.75 — 1.00
H.C. FE CR (Low Si)	.35 — .65
50% FE SI	.24 — .34
H.C. FE CR (High Si)	.20 — .30
CA C_2 (Continuous)	.19 — .22
(Packets)	.28 — .32
75% FE SI (Continuous)	.16 — .20
(Packets)	.25 — .30
FE CR SI (2-Stage)	.12 — .17
SI MN	.10 — .15
STD. FE MN	.08 — .13

(FIGURE I)

The high-carbon ferrochrome (low silicon) designates the normal sales grades of ferrochrome containing 4-6% carbon and 2% silicon. High-carbon ferrochrome (high silicon) indicates the process grades of alloy containing approximately 6% silicon, but also encompasses present day charge chrome and minimum 7% carbon grade. Each of the specific grades of ferrochrome will demand its own specific range of electrical conditions.

Most of the figures represent data taken from covered three-phase furnace operations, although, open furnaces and single-phase furnace data are also included and fall in the same ranges. Two ranges are shown for both calcium carbide and high per cent ferrosilicons. In both cases the higher range represents the electrical conditions employed by the old design rectangular packet furnaces.

The range of electrical conditions represented by these figures constituted a challenge to the development of a furnace design principle that would relate electrical, dimensional and metallurgical requirements. For each operation where sufficient information was available, a study was made of the relationship of electrical conditions to such factors as efficiency, recovery, alloy composition and similar performance characteristics. The random design experience of the industry had resulted in furnaces of quite different dimensions and electrode sizes for given loads, and data were available for given operations at widely different power densities. A broad relationship between power density and "k" factor has gradually been accumulated for most of the major products shown in Figure II. Part of these data were compiled from information gathered in Europe which allowed an extrapolation not previously available from Electro Metallurgical Company data alone.



(FIGURE II)

These curves in Figure II do not represent all of the random operating experience available. Rather, they are selected data representing what is known to be satisfactory working areas for fully competitive performance. Operations on many of these products at "k" factors far removed from the indicated relations are often encountered in the industry. For example, 50% ferrosilicon has often been produced at a "k" factor of 0.15 compared to the level above 0.30 shown on the curve. Such operations were normally substandard in some performance phase, and the indicated curves represent satisfactory operating conditions so far as present knowledge can define them.

It was previously noted in connection with Figure I that packet furnace data for calcium carbide and high per cent ferrosilicons indicated consistently higher "k" factors than did continuous electrode furnaces. The slopes of the curves for these products in Figure II are thus determined. One of the notable features of the packet furnaces was invariably the fact that much lower power densities, in terms of kw/sq. in. of electrode cross section, were employed as compared to the continuous electrode furnaces. This fact raised the question of whether there was an electrode "shape factor" to be taken into account. The inclusion of European data, where operations are generally conducted at lower power densities, provided curves of the same general slope for continuous electrodes as those derived from packet furnaces. The curve for standard ferromanganese is a typical example of data derived only from continuous electrode operations. It was thus concluded that shape of the electrodes did not have a major distorting influence.

Other curves shown included both single-stage and two-stage ferrochrome-silicon, an experimental aluminum-silicon operation previously published, and low-silicon high-carbon ferrochrome.

If the voltage and current were both held constant for a particular operation while the electrode size was increased, the result would be a lower power density and higher "k" factor. A theoretical curve for such a case is also shown on Figure II and the slope represents the effect of changing electrode size at constant voltage and current values. Note that the actual curves tend to exceed the slope of the theoretical curve and, therefore, represent a real change in electrical conditions attributable to the power density.

The initial stages of design for a submerged arc furnace must take these electrical relations into account. No other

feature of furnace design can be properly determined until the desired "k" factors for the products in question have been determined and suitable power densities are in mind. Proper evaluation of these relations depends on the accumulation of a wide variety of operating results. The elaboration of this data, however, can provide a reliable and permanent basis for submerged arc design tailor-made to the product under consideration.

Electrode Size

It has been the practice to select electrode size for a submerged arc furnace based on the anticipated current density for the operation contemplated. In general, an arbitrary decision is made concerning the power to be integrated and economics has dictated the highest possible current density in order to keep capital cost to a minimum. Expressed another way, it has been the practice to operate a given unit at the highest load that the electrodes would allow in order to extract maximum production from the unit; normally this maximum production does not coincide with the point of optimum performance.

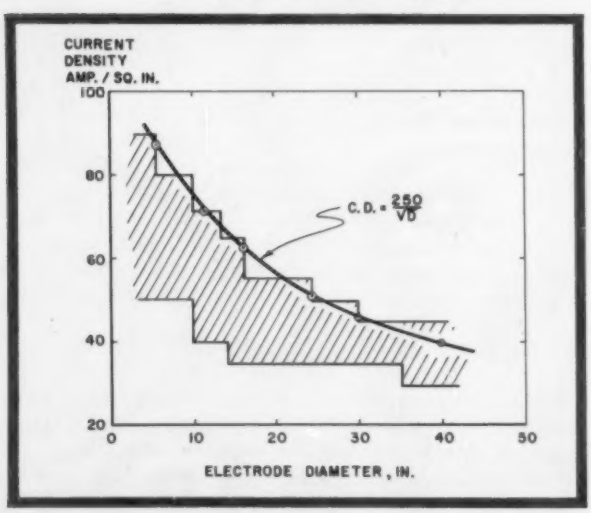
For the purposes of consistent design, it is necessary to bear metallurgical results in mind and some factor other than electrode size might more appropriately be made the limiting factor. Once the unit is properly arranged for optimum performance, it can then be operated at the proper economic level with a reasonable insight into the consequences. Selecting electrodes by current density is unsatisfactory since it tends to provide for good electrode performance without regard to metallurgical performance. Since reasonable limits to current density are important, it becomes necessary to relate this parameter to the other electrical conditions dictating the furnace design.

Figure III presents a graphical illustration of the generally accepted current density values for standard prebaked carbon electrodes. Superimposed on this graph is a curve derived from the empirical equation:

$$C = 250/\sqrt{D}$$

where C = current density, amp./sq. in.

D = electrode diameter, inches



(FIGURE III)

This equation represents the high edge of the current density range as shown by the graph and should provide a useful basis for furnace design which would assure satisfactory electrode performance.

This guide to maximum current densities plays a most important role in operations having a low "k" factor, such as standard ferromanganese where current densities at suitable power densities always tend to run high. Many other operations utilizing high "k" factors will be properly designed at current densities far below this maximum guide.

Under the present system of design, the first estimate of electrode size would be made from the power density – "k" factor relations of Figure I. Choice of power density should be influenced by accumulated experience, ability to obtain the corresponding "k" factor—taking transformer limitations and reactances into account, and finally by the effect of these choices on electrode current density using Figure III as a guide.

For example, suppose it is desired to design a 7000 kw. standard ferromanganese furnace. By selecting points from the appropriate curve relating power density and "k" factor (Figure II), it is possible to calculate the required electrode size, arc voltage and secondary current to satisfy that relationship. The resulting current densities can then be checked against the current density guide until values approaching the curve $C = 250/\sqrt{D}$ are obtained. Thus satisfactory conditions for both metallurgical performance and electrode performance are obtained. Actual figures for the case in question are tabulated. These calculations show that for a 7000 kw. load, a power density of 2.2 requires an electrode of 37 inches diameter but results in an excessively high current density for good electrical performance.

SELECTION OF ELECTRODE SIZE
STANDARD FERROMANGANESE

DESIRED LOAD KW 7,000 KW-3 PHASE			
"K" FACTOR (from curve)	.10	.14	.12
POWER DENSITY	2.2	1.8	2.0
ELECTRODE SIZE FOR P.D.	37	40	38.5
ARC VOLTAGE	45	51	49
SEC CURRENT	52000	45500	49400
CURRENT DENSITY	48.5	35	42.5
ALLOWABLE C.D. (from guide)	42	40	41

(FIGURE IV)

Assuming there is a choice of standard sizes in prebaked electrodes, a 35 inch diameter would be eliminated from consideration and a 40 inch diameter, being the next larger standard size, would be chosen. This electrode would result in a slightly lower power density and allow a slightly higher "k" factor. The current density in this case would be below the maximum considered satisfactory. An academic balance would indicate an electrode of 38.5 inches should be chosen to arrive at agreement between allowable and actual current densities within the limits of the other electrical requirements.

Electrode Spacing

After determination of desired load, electrical relationships and electrode size, the next important feature of three-phase furnace design to be determined is electrode

spacing. In the past, this has been arrived at by experience and various arbitrary relations. One design method commonly employed has been to allow a clearance between electrodes equal to one electrode diameter. For relatively easy smelting operations, this is sometimes increased to two electrode diameters. Many of the covered all-purpose furnaces in the industry have a typical electrode spacing of 1.5 diameters clearance. This dimension has been dictated, at least in some degree, by the clearance requirements for accessory equipment over the furnace and has only passing relationship to metallurgical performance. In some operations such as continuous electrode smelting of high per cent ferrosilicon, it has been found desirable to compress this spacing to nearer one electrode diameter clearance.

Recently, an attempt was made to develop a design theory along the lines that electrodes represent point sources of heat and that the heat radiated spherically in all directions. Under this assumption, the electrode spacing could be related to the cube of the reaction zone diameter. If a suitable spacing were known for a given operation at a fixed power input, it would be possible to design furnaces of any other size based on this proportionality. At low power densities, the assumption that the electrodes represent point sources of heat becomes less and less valid. The heat does not radiate spherically, partly as a result of the reflecting effect of the large electrode itself. This approach was therefore discarded in favor of the theory that power is dissipated over a fixed area of reaction zone and the kilowatt input is proportional to the square of the reaction zone diameter.

In order to test the relationship between electrode spacing and power input, data were accumulated from 50% ferrosilicon operations where the greatest variety of furnace sizes and loads was available. On the assumption that operating experience had led to a proper electrode spacing for the furnaces of various loads, the linear, area and volume proportionalities were calculated. The results of the area calculation are shown in Figure V.

ELECTRODE SPACING VS LOAD
50% FERROSILICON

ACTUAL FCE LOAD, KW.	ACTUAL SPACING, FT.	CALCULATED SPACING, FT.	RATIO CALC./ACTUAL
12000	8.5	9.2	1.08
10900	8.5	8.8	1.03
10560	8.5	8.6	1.01
10100	8.5	8.4	.99
11400	8.0	8.9	1.11
11050	8.0	8.8	1.10
10770	8.0	8.7	1.08
9500	8.0	8.1	1.01
7570	6.0	7.3	1.21
4320	5.5	5.5	1.00
4150	5.0	5.4	1.08

(FIGURE V)

The basis for the calculated spacings was taken to be an 8.5 foot spacing at a load of 10250 kw. This relation was selected due to a long record of particularly good furnace performance under these conditions.

Using the linear proportionality, a ratio of calculated to actual spacing for the furnaces in question ranged from 0.68 to 1.18, or a net range in ratio of 0.5. The volume proportionality resulted in a net range in ratio of 0.28 while the area relation gave the lowest net range of 0.22. General agreement between actual and calculated spacings was good throughout the entire range on an area basis, while the volume relations tended to stray off at the low end and the linear relation deviated widely at both ends of the range.

These data, and knowledge of the actual performance characteristics of all the furnaces listed, were taken as adequate indication that a furnace design rationalization based on an area concept was preferable to one based on either a linear or volume principle. It appeared satisfactory to assume that furnace load is proportional to the square of the electrode spacing.

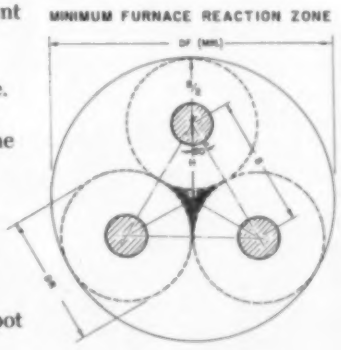
Fundamental furnace design data for each submerged arc operation can be collected by studying the performance of existing furnaces and arriving at load and spacing relationships that are proved satisfactory. Any other furnace size can be properly dimensioned based on this proportionality.

Reaction Zone and Crucible Diameter

With the acceptance of the area concept of power dissipation in a submerged arc furnace, it becomes possible to speculate on the size of reaction zones and to relate these zones to electrode spacing.

The first insight into the relationship is provided by determining the minimum possible reaction zone. Figure VI shows the relationship between minimum reaction zone diameter and electrode spacing for a triangularly arranged furnace. In this figure, minimum reaction zones are drawn about each electrode so that the edges just touch between electrodes. By normal trigonometric relations it can be shown that this minimum reaction zone diameter, D_r, is equal to the electrode spacing and that the minimum furnace diameter, D_f, circumscribing these reaction zones is equal to 2.16 times the spacing. Thus when: $D_f = 2(H + \frac{S}{2}) = 2.16S$, $D_r = S$.

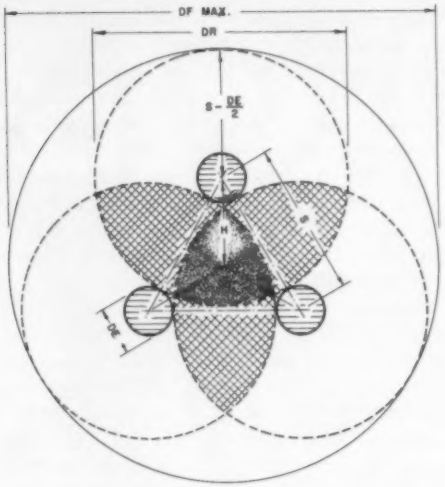
It stands as self-evident that this arrangement would measure the minimum reaction zone. Any diameter less than this would not allow the flow of fluid materials from one electrode to another. In fact, the shaded area at the center junction of the three zones represents an undesirable dead spot in the furnace.



(FIGURE VI)

For the other extreme, a maximum reaction zone was assumed to be one in which the edge of one reaction zone extended to the edge of the electrode centered in an adjoining reaction zone, as shown in Figure VII. In this case, it can be shown that the maximum reaction zone D_r is equal to twice the spacing, less the diameter of one electrode. Thus when: $D_f(\text{Max.}) = 2[H + (S - \frac{DE}{2})] = 2.31S - DE$, $D_r = 2S - DE$.

MAXIMUM FURNACE REACTION ZONE



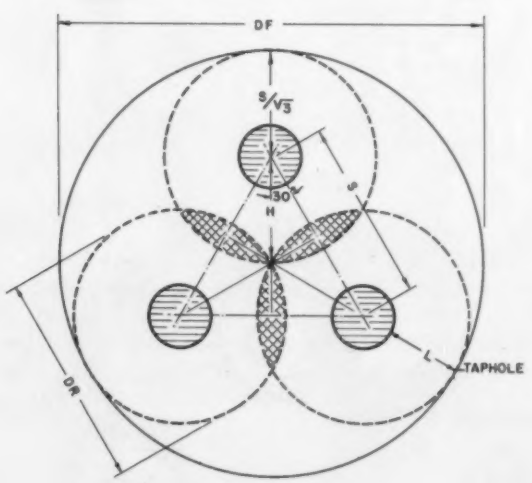
(FIGURE VII)

The maximum furnace diameter, D_f, circumscribing these reaction zones is represented by the equation shown in the figure.

In the center shaded area in this case, all three reaction zones overlap, in what would be an overly active and uncontrollable region of a submerged arc furnace. This represents the opposite undesirable extreme from the dead zone between minimum reaction zones.

After studying these extremes, it was concluded that an optimum furnace reaction would be one in which adjoining zones slightly overlapped and where all three just touched in the center, without leaving either a dead or an overactive center area. Such a condition is shown in Figure VIII. This diagram indicates that the relationship between reaction zone and electrode spacing is for the reaction zone to be equal to 1.16 times the spacing. The active furnace diameter corresponding to these reaction zones would then be 2.3 times the spacing. Thus when: $D_f = 4H = \sqrt{\frac{4S}{3}} = 2.3S$, $D_r = \sqrt{\frac{2S}{3}} = 1.16S$.

OPTIMUM FURNACE REACTION ZONE



(FIGURE VIII)

Furnace Shell Diameter

The foregoing equations provide a basis for determining the diameter of the actual furnace crucible. Practical experience has indicated that it is not desirable to have the molten zone contact the furnace lining. It appears that an empirical addition to the calculated furnace diameter, D_f, is desirable. Existing furnace data suggest that the diameter of crucible inside the lining should be approximately $1.15 \times D_f$.

In the design of many furnaces, it has been customary to place the center of the electrode triangle slightly in front of the center of the shell. This practice tends to ensure that the tap hole area is the weakest part of the furnace and burnthroughs are not likely to occur at other places around the circumference. This practice tends to result in shells of larger diameter than necessary and it is recommended that the center of the electrode triangle and furnace shell coincide. In the case of rotating hearth furnaces, this symmetry is essential.

One of the critical furnace dimensions is the distance from the electrode face to tap hole and in order to satisfy this dimension, the electrode triangle has been moved forward. This distance varies for different operations for the same reason that electrode spacing varies; i.e., due to varying refractoriness of the materials being smelted. The electrode spacing and distance to tap hole should be related. From Figure VIII, it can be seen that distance from electrode face to reaction zone can be expressed by the equation $L = \sqrt{\frac{S}{3}} - \frac{DE}{2}$

Furnace Depth

One of the most difficult features of furnace design to reduce to formal relationships is furnace depth. Various empirical approaches in the past have included such relations as voltage per foot of depth, without being adequate measures of depth requirements. Using the theory that electrode tips are point sources of heat, the suggestion arises that power input is proportional to the cube of depth. This relation does not seem to bear out in actual practice and the point source theory was discarded in the case of electrode spacing.

Observation of many furnace reaction zones during digouts and repairs has led to certain useful information. In smelting operations such as the ferrosilicons, ferrochrome-silicon and aluminum-silicon alloys, it has been noted that a highly conductive matrix of hearth metal fills the bottom of the furnace to a depth within inches of the point that the electrode tips have operated. In certain operations where electrode tips have normally been 60 inches off hearth, there will be upwards of 55 inches of conductive hearth metal beneath the electrode.

It has been customary to think of the interior of a submerged arc furnace as being occupied by materials in progressively more complete states of reduction, ranging from raw materials at the surface to final product at the hearth line. The heavy layer of hearth metal always encountered, now suggests that the furnace is actually divided into two relatively distinct zones. Below the electrode tips is the observed hearth metal of high conductivity, reasonably uniform composition, and essentially reacted material. Above the electrode tips are the unreacted and partially reacted raw materials of relative nonconductive nature.

In the upper zone of the furnace, heat transfer must be

preponderantly through the mechanism of convection, since this is the zone where reaction occurs and hot reaction gases are rising. In the lower zone, relatively little gas passes to aid convection. The more highly conductive nature of the hearth metal suggests heat transfer in this zone is predominantly by conduction.

From a practical operating standpoint, it is desirable to suffer as little heat loss as possible and the temperature of the off-gases from the surface of the furnace should be kept to a minimum. This factor governs the desired furnace depth from mix surface to electrode operating depth. On this basis, the upper portion of the furnace can be treated essentially as a packed tower with heat being transferred from the hot gases to the particles of mix.

The usual relationships for such a case indicate that the rate of heat flow is directly proportional to the unit heat transfer surface, the coefficient of heat transfer, the cross sectional area of the mix bed, the depth of heat transfer bed and the temperature difference.

In the design of an electric furnace for a given smelting operation, the transfer coefficient and unit heat transfer surface would be constant mix characteristics determined by the raw materials for any size furnace. Similarly, the desired temperature difference would be a constant. A previous relation has indicated that the electrode spacing and the area should be proportional to the load.

Under these circumstances it is evident that the rate of heat flow is directly proportional to the depth. It is indicated that at constant power density, the depth of mix from electrode tip to surface would be constant for any size furnace. With increases in power density, this depth should be increased proportionately.

The lower portion of the furnace burdened with hearth metal can be represented as a large heat conductor where flow of heat is directly proportional to thermal conductivity, area and temperature differential, and inversely proportional to depth.

For a given smelting operation, both thermal conductivity and temperature differential are constants and the rate of heat flow is directly proportional to the area and inversely proportional to the depth of hearth metal. Since the sensible heat in tapped metal is a significant energy loss, it is desirable to tap at the lowest temperature consistent with the hot metal handling techniques and skulling characteristics of the alloy involved.

For any given power density and accompanying heat distribution pattern, the amount of heat lost in the tapped metal would be dependent on the depth of hearth material. An increase in power density would tend to demand an increased depth of hearth metal to keep conducted heat from increasing. It is concluded that the two zones of depth should be constant for constant power density, regardless of total load, and increases in power density must be accompanied by proportional increases in furnace depth to maintain the same level of heat losses.

Although these concepts of heat flow in a submerged arc furnace are oversimplifications of actual conditions, they nevertheless provide a consistent basis for design.

A useful relationship, therefore, becomes the ratio of inches of electrode submerged in the mix to the distance of electrode tips off hearth. This ratio varies widely with different smelting operations and typically ranges from 3.0 to 0.3 for the normal alloys produced. Knowledge of these values materially aids in proper furnace design for a given operation.

Dimensional Relations — Packet & Continuous Electrode Furnaces

Before the days of covered submerged arc furnaces, a common design arrangement was a rectangular furnace shell with three rectangular electrodes arranged in line. These rectangular electrodes were made up of groupings or packets of square carbons. Hence, this type of furnace became known as a packet furnace.

Look Ahead— Look Electric

Gives greatest flexibility — Makes any steel — any time — from stainless to plain carbon. Handles cold scrap, metallics, hot metal. Starts, stops quickly — gives faster melts.

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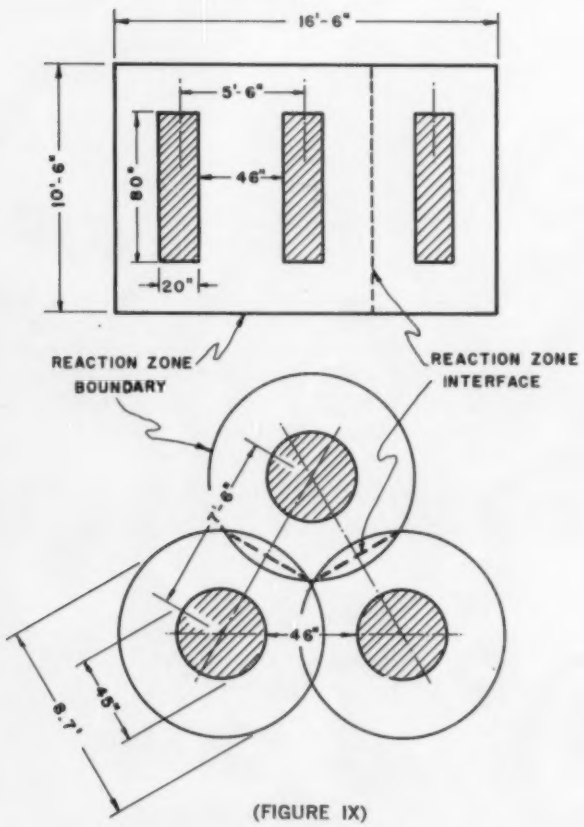
One of the more difficult problems in the past has been the translation of results from packet furnaces to continuous electrode furnaces. Many operations have been repeatedly demonstrated to be less satisfactory in continuous electrode furnaces than in packets.

Some of the more obvious differences in conditions of packet furnace operation have been the higher "k" factors and very much lower power densities that they employed. In order to design a continuous electrode furnace with the characteristics of a packet furnace, the concept of minimum reaction zone was applied to packets.

A typical packet electrode arrangement is exemplified by furnaces using three 20" x 80" electrodes arranged in a line on 5'6" centers or with 46" clearance between electrodes. A minimum reaction zone, therefore, extends midway between electrodes, or approximately two feet. If it is assumed that the reaction zones extend out equally all around the electrode, it is possible to determine the entire furnace reaction zone size.

8500 KW FERROSILICON FURNACES



(FIGURE IX)

The reaction zone shown for a typical packet furnace measures 10.6 x 16.6 feet, based on the minimum reaction zone concept. It is interesting to note that actual reaction zone measurements made on this type of furnace have verified within inches the estimated reaction zone size.

Under the assumption that the reaction zone extends to the center of the area between electrodes, the two reaction zones of adjacent electrodes must join for the full length of the electrode. In continuous electrode furnaces, the minimum reaction zones join only at a point. A condition more comparable to the packet furnace, therefore, is the optimum reaction zone where the zones overlap slightly to approximate the line contact between packets. With this reasoning as a basis, it is then possible to approximate packet furnace conditions in a continuous electrode furnace.

A continuous electrode furnace equivalent to this packet would have 45" electrodes on 7' 6" centers. The electrode power density in both cases is 1.76 kw/sq. in., the reaction zone area per electrode is equal (58 sq. ft.) in both cases and therefore the reaction zone power density is equal at 49 kw/sq. ft. and the distance between electrodes is essentially equal in both cases.

It is felt that the application of these principles to continuous electrode furnaces, based on packet furnace data, would allow the solution to many metallurgical problems characteristic of the continuous electrode furnaces. The trend indicated for continuous electrodes, based on comparison with the older packets, would be to larger diameters for existing loads.

Conclusion

These design principles have been gradually evolved and applied so far as possible in the solution of various metallurgical problems. It is fully recognized that a vast amount of additional information is desirable and that certain of the present concepts are controversial. It is strongly felt, however, that the continued development of submerged arc furnaces depends upon the formulation of a system of design that relates the two important elements involved – electricity and metallurgy. It is hoped that this presentation will stimulate interest in the problem of proper metallurgical design and will serve as the basis for the continued development of much more complete design relationships.

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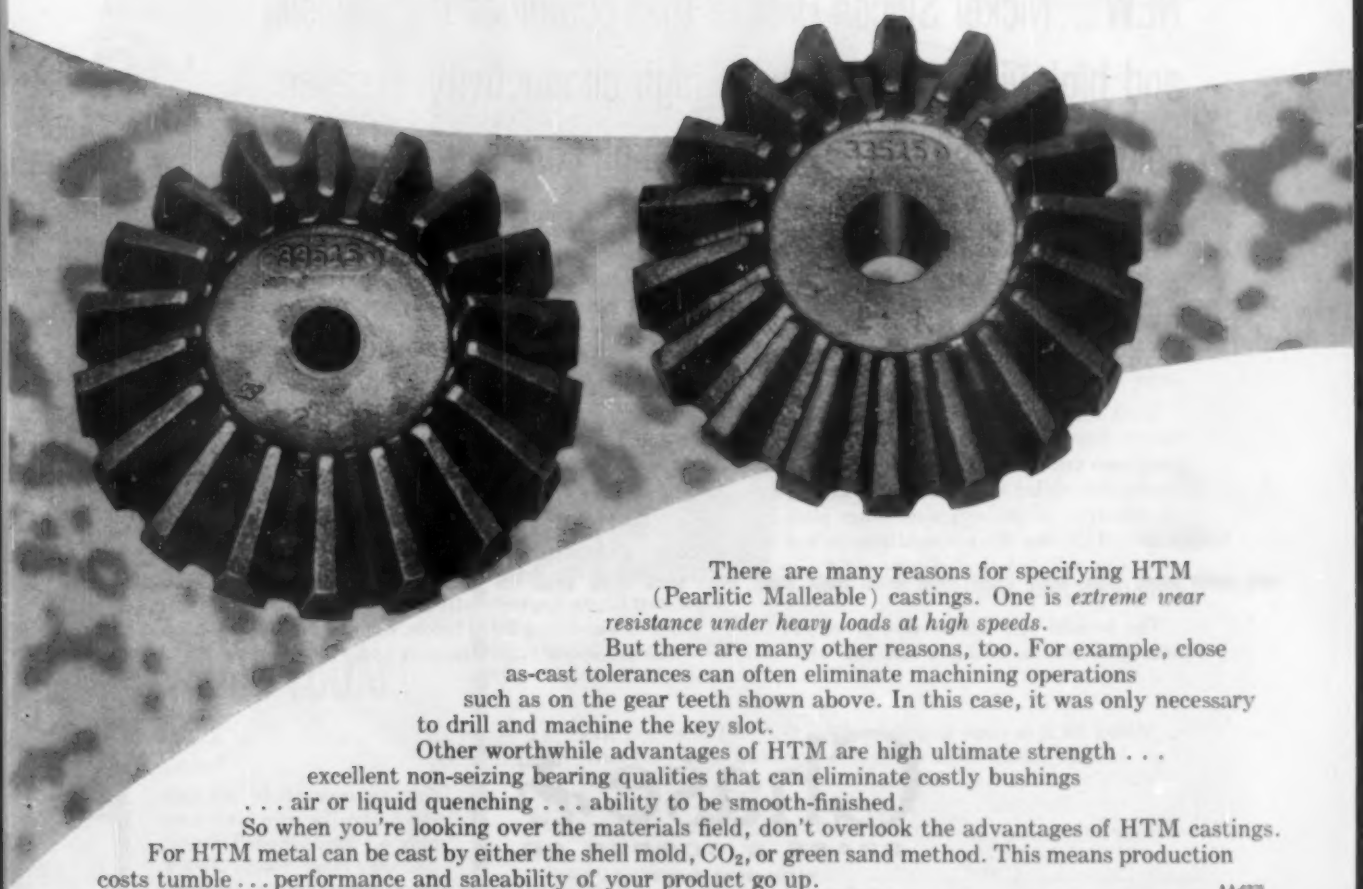

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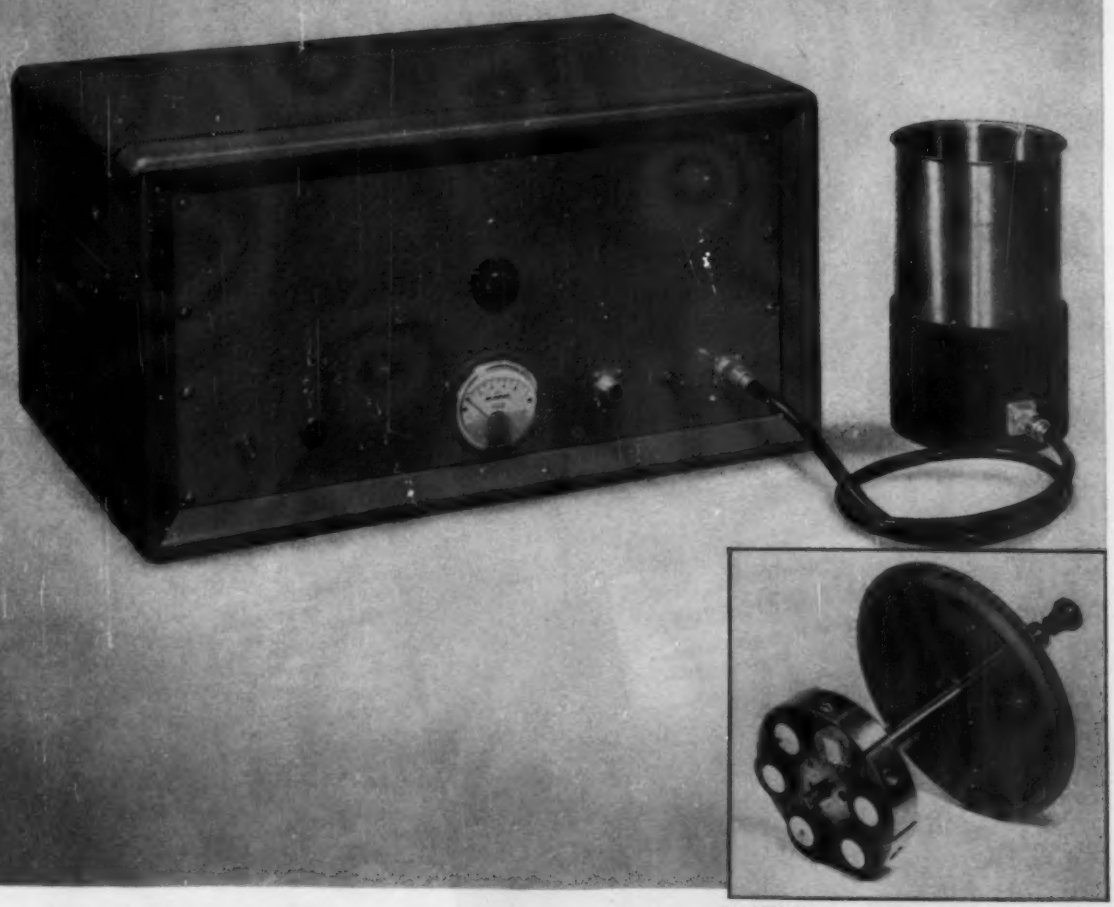

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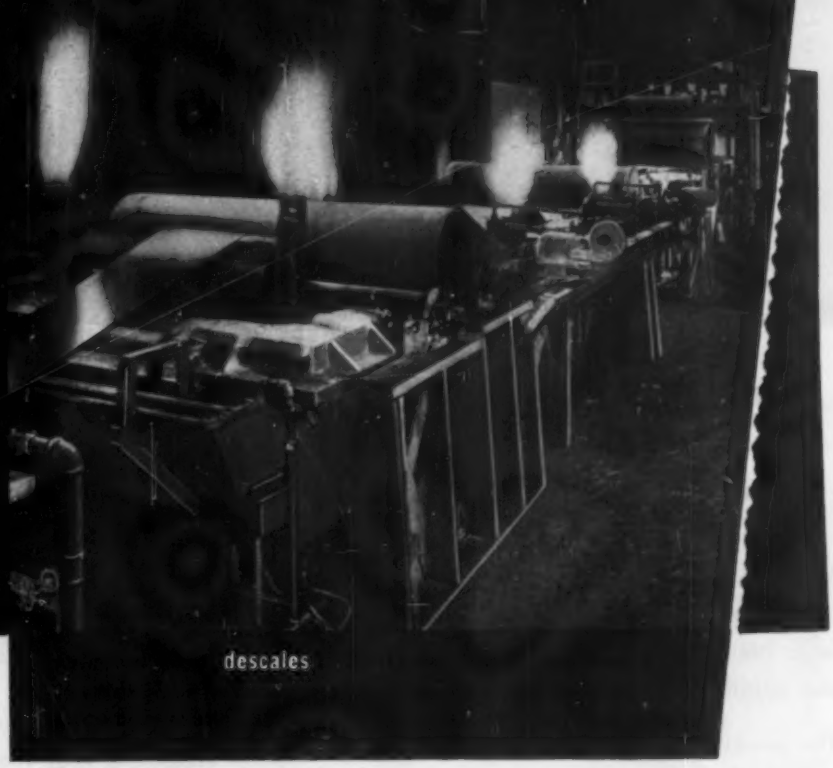

The above 35'-0" long Drever Continuous Descaling Bath will descale 18,700 lbs/hour when strip enters bath at bath temperature. Entering strip temperature is controlled by regulation of quenching temperature after strip is discharged from a catenary annealing furnace.

Drever descaling baths are heated by gas-fired immersion tubes with proportioning automatic temperature control.

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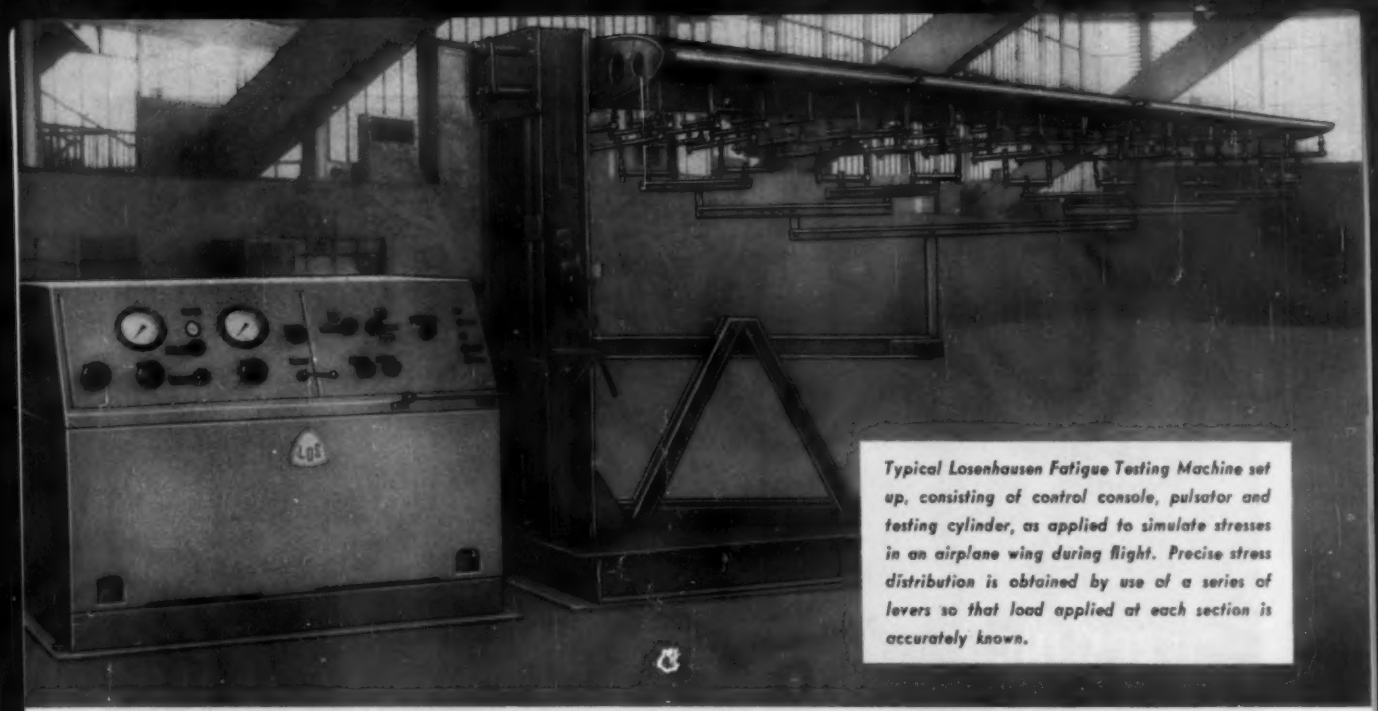

Typical Losenhausen Fatigue Testing Machine set up, consisting of control console, pulsator and testing cylinder, as applied to simulate stresses in an airplane wing during flight. Precise stress distribution is obtained by use of a series of levers so that load applied at each section is accurately known.

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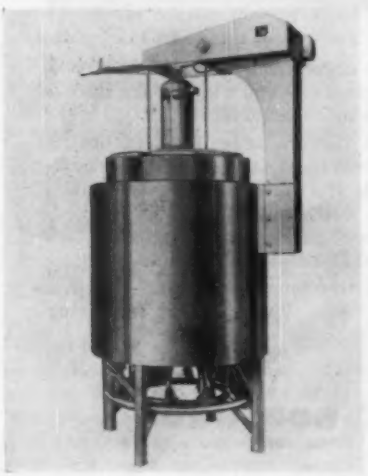
APPLICATION and EQUIPMENT

Gas-Fired Furnace

A new carburizing-nitriding furnace has been announced by the Pacific Scientific Co. It can be used for all types of general heat treating work at temperatures to 1850° F. A three-point air lifting action raises and lowers the cover. This insures a positive seal and eliminates any possibility of damaged gaskets or cover misalignment. A fan in the

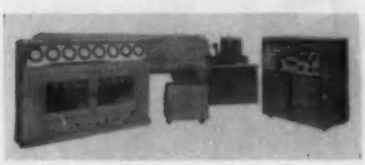


cover provides for uniform heating and atmosphere distribution. It is mounted rigidly, while the motor is mounted flexibly. Radiant-type Inconel tubes are fired individually or on a multiple basis. The furnace is available as an electrically heated unit in a number of standard sizes and capacities.

For further information circle No. 951 on literature request card, page 48-B.

Spectrograph

An interchangeable direct reading attachment for a high resolution spectrograph has been announced by Baird-Atomic, Inc. This permits a



3-meter grating spectrograph to be used for routine control as well as research studies. The direct reading attachment presents, as per cent concentration, readout of eight elements in less than 2 min. A monitor, incorporated into the direct reading attachment, corrects angular deviations of less than ¼ sec. of an arc. An electronic slit setting attachment permits realignment to eight different elements in less than 1 hr.

For further information circle No. 952 on literature request card, page 48-B.

Brazing Alloy

American Brazing Alloys Co. has announced high-tensile nickel silver brazing rod in five diameters bare (1/16 to 1/4 in.) and four diameters with flux coating (3/32 to 1/4 in.). Its melting point is 1700° F.; Brinell hardness, 160 to 170; tensile strength, 80,000 psi.; and shear strength, over 150,000 psi. Its A.W.S. classification is BCuZn-6.

For further information circle No. 953 on literature request card, page 48-B.

Radiography

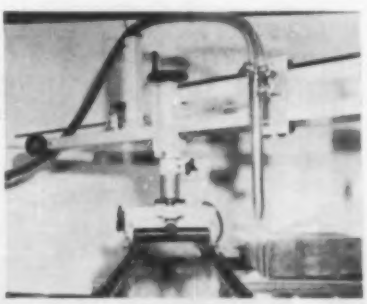
A new industrial radiography unit has been announced by the Instruments Div., Philips Electronics. The MG 100 weighs 45 lb. and is housed in an enameled steel case measuring

16 by 12 by 6¾ in. It is connected to the tubehead through a flexible multiconductor cable. Kilovoltage regulation is stepless and is continuously variable from 30 to 100 Kvp. The X-ray generator and tube are enclosed in a steel tank weighing 55 lb. and measuring 9½ by 10¼ by 14 in. The 1 mm. focal spot is eccentrically located within the tubehead, closer to the port, permitting shorter focal-film distances. The radiation angle is 42 deg.

For further information circle No. 954 on literature request card, page 48-B.

Gas Welding and Cutting

A portable machine that can be equipped to do automatic welding, cutting and heat treating, has been announced by the NCG Div. of National Cylinder Gas Co. One model travels at welding speeds of 9 to 127 in. per min. and the other at 1 to 14½ in. per min. for cutting or heat treating. The new machine with electric



motor, controls and heavy aluminum housing weighs 47 lb. Beam assemblies are available in two lengths —74 in. for cutting and 49 in. for welding. The beam can be raised to 41½ in. above the straight 10-in. track of rolled steel.

For further information circle No. 955 on literature request card, page 48-B.

Heat Treating Furnaces

New features for its straight-through heat treating units have been announced by Ipsen Industries, Inc. Quiet gas burners of alloy construction operate without tail flames. A 100% air-gas premix system, new ceramic heating tubes, links which will withstand temperatures to 2800° F., one-piece cast fan and shaft assemblies, cast Meehanite door plates with machined ways to improve sealing, heavier alloy frame inner doors,

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A phone call or letter to your nearest L&N office or to 4927 Stenton Ave., Phila. 44, Pa. will bring more information. Ask for data sheets.

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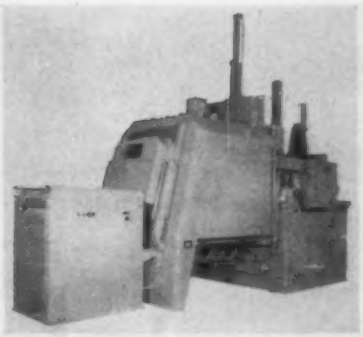
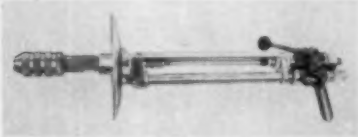


and new design of refractory arch for increased strength are included. The cooling capacity has been increased by the use of multiple-finned cooling tubes.

For further information circle No. 956 on literature request card, page 48-B.

Cutting

A new powder lance has been announced by Linde Co. Accurate control of intense heat is the key to its operation. Lengths of standard black iron pipe are fitted into its front end, which is connected to an oxygen supply and a source of special metallic powder. The oxygen and metallic

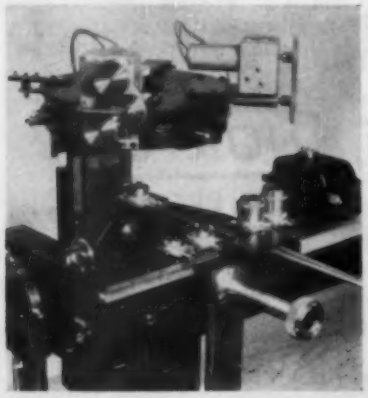


powder are mixed in the pipe and carried to the material being pierced or cut by the consumable pipe. This mixture is ignited at the end of the iron pipe, producing an extremely high temperature reaction that melts both ferrous or nonferrous material in its path.

For further information circle No. 957 on literature request card, page 48-B.

Metallurgical Microscope

The Reichert remote-control metallurgical microscope has been announced by William J. Hacker &



Co. Compact design and relatively small size, reduce over-all dimensions, weight and cost of lead shielding. The specific design of the phase contrast, microhardness testing and darkfield equipment, enable these techniques to be applied in quick succession without either removing the specimen or altering the set-up of the instrument.

For further information circle No. 958 on literature request card, page 48-B.

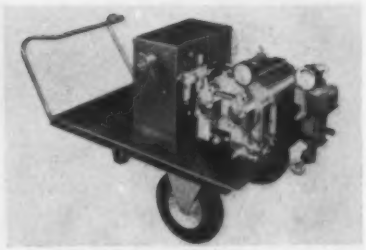
Grain Refiner

The Conversion Chemical Corp. has announced a new leveling and grain refining agent for cadmium plating solutions producing semi-bright deposits. This agent has been designed to modify the grain structure of cadmium plate for uniform results with chromate conversion coatings. It improves the throwing power of the bath and reduces burning.

For further information circle No. 959 on literature request card, page 48-B.

Pump

Nordson Corp. has announced a new pumping unit for use in their spray coating systems. It features overlapping piston action, automatic speed control, self-cleaning piston rods, throw-away packing glands,

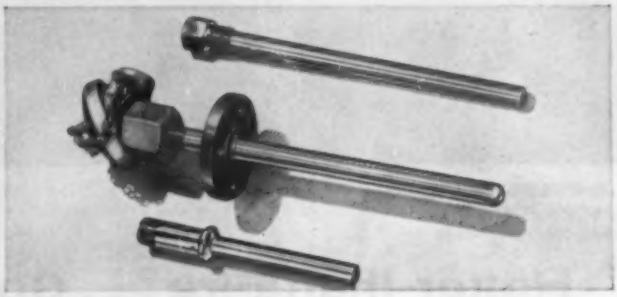


chromium plated air cylinders and complete accessibility of all expendable parts with a minimum of disassembly. Designed to operate at pressures up to 1500 psi. and at temperatures up to 500° F., this new pump can be used for applying all types of coating materials including plastisols and hot melt resinous materials. It delivers material at the rate of 1½ gal. per min. permitting multiple spray gun hookup.

For further information circle No. 960 on literature request card, page 48-B.

Zinc Brighteners

Allied Research Products has announced two new brighteners for cyanide zinc plating solutions—ARP 32, a powdered addition agent which provides brightness over the entire normal plating range found in still and automatic tanks, and ARP 53, a



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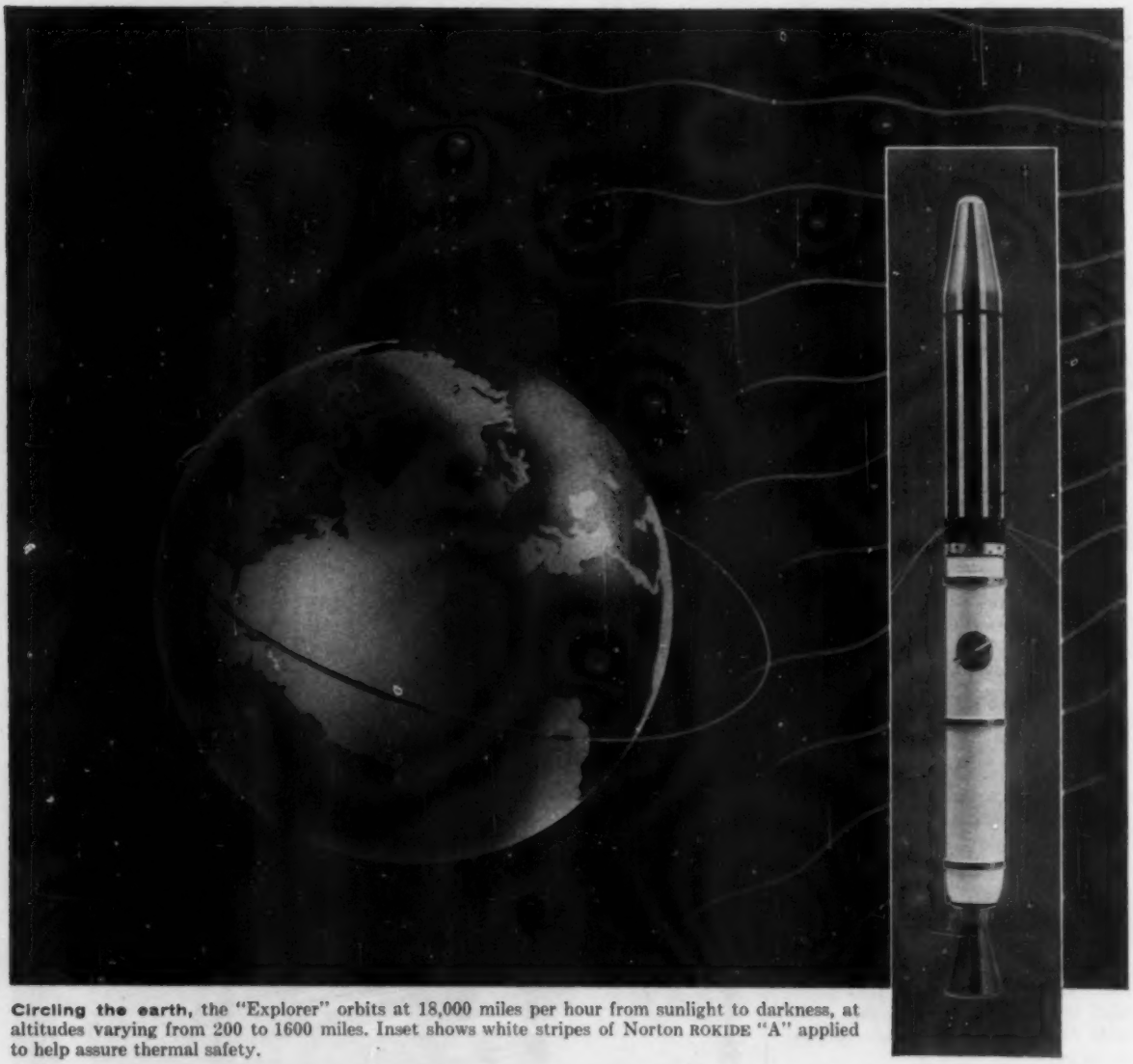

Circling the earth, the "Explorer" orbits at 18,000 miles per hour from sunlight to darkness, at altitudes varying from 200 to 1600 miles. Inset shows white stripes of Norton ROKIDE "A" applied to help assure thermal safety.

Hotter than Fire . . . Colder than Ice

ROKIDE* coating protects the "Explorer" through temperatures from 600°F to 150° below zero.

Completing its orbit every 118 minutes, the "Explorer" speeds between blazing daylight and black night every hour, through temperatures ranging from 600°F to 150°F below zero.

The resultant thermal risks, especially to instruments, are enormous. But by striping the satellite's nose cone and instrument section with ROKIDE "A" aluminum oxide spray coating, Jet Propulsion Laboratory scientists were able to maintain a safe internal temperature range.

ROKIDE "A", "ZS" and "Z" coatings are hard, crystalline refractory oxides. These Norton developments have high resistance to excessive heat, abrasion and corrosion that has proved valuable not only in reaction motors and AEC projects, but to general industry ..... in applications involving electrical insulation, electronics, bearing surfaces, erosion resistance, chemical barriers, material upgrading, surface catalyst activity and altering emissivity and characteristics of surfaces.

Facilities for applying ROKIDE coatings are maintained at NORTON COMPANY, Worcester, Mass., and at its plant 2555 Lafayette Street, Santa Clara, Cal. For the latest ROKIDE Bulletin write to NORTON COMPANY, 324 New Bond St., Worcester 6, Mass.

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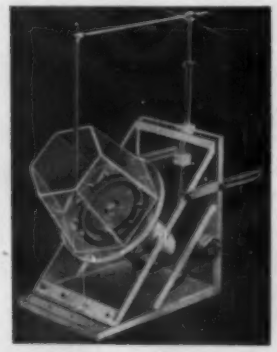
liquid addition agent for barrel plating. ARP 53 has a wide current density range. It is stable and may be added to conventional cyanide plating solutions already containing other brighteners.

For further information circle No. 961 on literature request card, page 48-B.

Finishing Barrel

A new laboratory unit for finishing of samples and small lots of all kinds has been announced by Belke Manufacturing Co. The hinge-mounted



drive tilts back for plating with the cylinder in oblique positions, and adjusts for burnishing with the cylinder in the horizontal position. Plating and burnishing cylinders are set on the drive shaft without fastening. Plating cylinders are of plexiglas and are available in two sizes with inside diameters of 5 in. deep, 4 in. diam. at small end and 5½ in. diam. at the large end; and 4 in. deep, 3½ in. diam. at the small end, 4 in. diam. at the large end. The burnishing cylinder is made of plexiglas with screw-on cover. Inside dimensions are 5 in. long and 4 in. in diameter. Motor is 115 v., 60 cycle, single phase.

For further information circle No. 962 on literature request card, page 48-B.

Vacuum Pumping

A new high-vacuum pumping system capable of reaching pressures as low as 5 x 10^{-7} mm. Hg has been announced by the Vacuum Equipment Div. of the New York Air Brake Co. It is used in the evacuation of such laboratory equipment as vacuum tanks, bell jars, vacuum furnaces and experimental vacuum tubes. It can be rolled on its casters from one location to another as required. Its high-vacuum pumping system consists of a high-speed, fractionating oil diffusion pump with a cold trap and a two-stage, gas-ballasted mechanical vacuum pump. Connected to the vacuum pumping system is a manifold-valve

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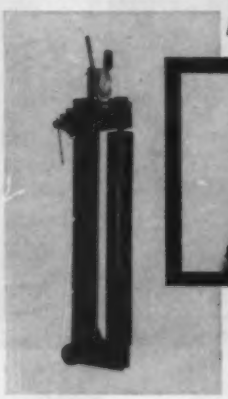
most versatile Hardness Tester ever made!



King Test Head in 30" base

King Test Head with Chain Adapter

King Test Head in 13½" base with King Brinell Scope

THE KING TEST HEAD CAN BE USED IN MANY INEXPENSIVE STANDARD ADAPTERS

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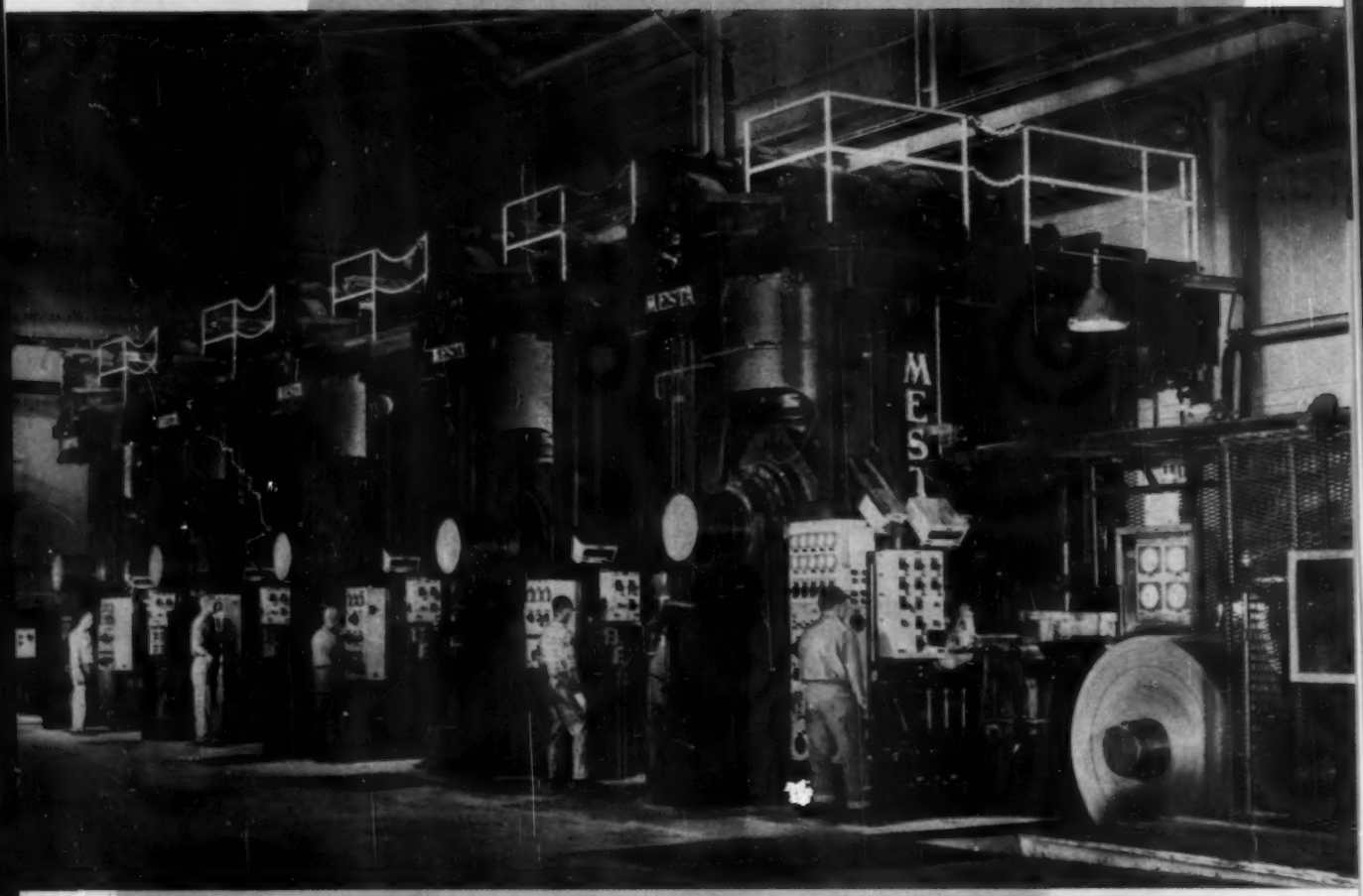
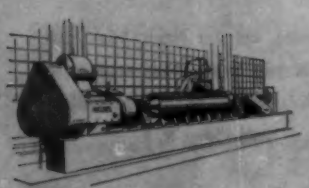
MESTA Cold Mills



MESTA 48" Four-High, Five-Stand Tandem Cold Mill
Rolling Strip Steel for Tin Plate in Coils



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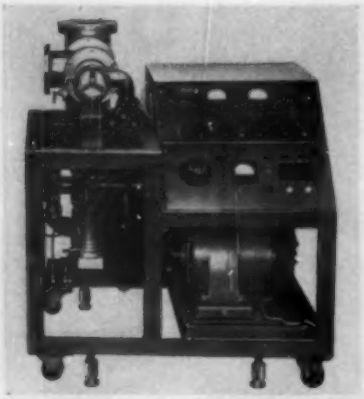
MESTA MACHINE COMPANY

PITTSBURGH, PENNSYLVANIA



arrangement with an intake fitting that can be rotated and indexed through 90 deg. from horizontal to vertical to permit connection with various types of vacuum chambers.

For further information circle No. 963 on literature request card, page 48-B.

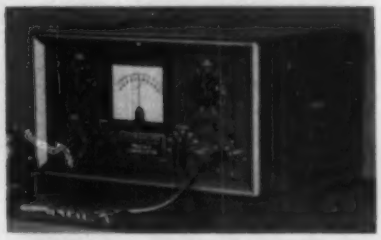
Resistance Alloys

A new iron-chromium-aluminum electrical resistance alloy has been announced by Hoskins Mfg. Co. Alloy 875 was developed for use as heating elements in industrial furnaces, kilns and other types of heating equipment where maximum continuous operating temperatures up to 2350° F. are required. The new alloy resists oxidation at high temperatures, has electrical resistivity of 875 ohms per circular mil foot at 68° F. and a specific gravity of 7.10.

For further information circle No. 964 on literature request card, page 48-B.

Metals Comparator

Sunshine Scientific Instrument has announced a nondestructive metals comparator for use with both ferrous and nonferrous metals. It can be used to test for composition, heat treatment, hardness, case depth, plating thickness, and other properties. The unit is basically an impedance



comparator, and will indicate changes in chemical and physical properties of a metal as these are correlated with the electrical and magnetic properties. Small duplicate parts, or pieces with equal cross-sectional areas, are usually tested by insertion in a test coil. A test head, placed against the metal being measured, is used on surfaces of large equipment, or parts too big to be inserted in a test coil.

For further information circle No. 965 on literature request card, page 48-B.

Thermocouples

The American Instrument Co. has announced a new thermocouple for use in pressure systems to 80,000 psi. and temperatures to 1000° F. Each thermocouple is built into a high-pressure compression fitting and can be installed by tightening a gland nut in the same manner as when making a superpressure connection. Assemblies consist of an iron-constantan or chromel-alumel couple welded at the tip. The plug and sheath of the thermocouple tip are made of Type 347 stainless steel.

For further information circle No. 966 on literature request card, page 48-B.

Hardness Tester

Opto-Metric Tools, Inc., has announced a machine for Rockwell hardness testing of long, heavy or bulky work such as shafts, spindles, forgings, castings, dies, without resorting to portable testers. To support such work an extra large table 40 by 10 in.

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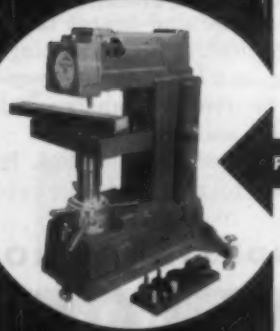
2 Applications (REGULAR AND SUPERFICIAL) 1 Tester



Hundreds of installations over the past few years have proved the economy of the only hardness tester which combines all scales of Rockwell Test (15 to 150 kg. loads).
The Kentrall cuts costs because it does the job of two conventional testers, requires only half the space and maintenance. Write for more detailed information, plus a list of prominent users who have switched to Kentrall.

PRICE $750.

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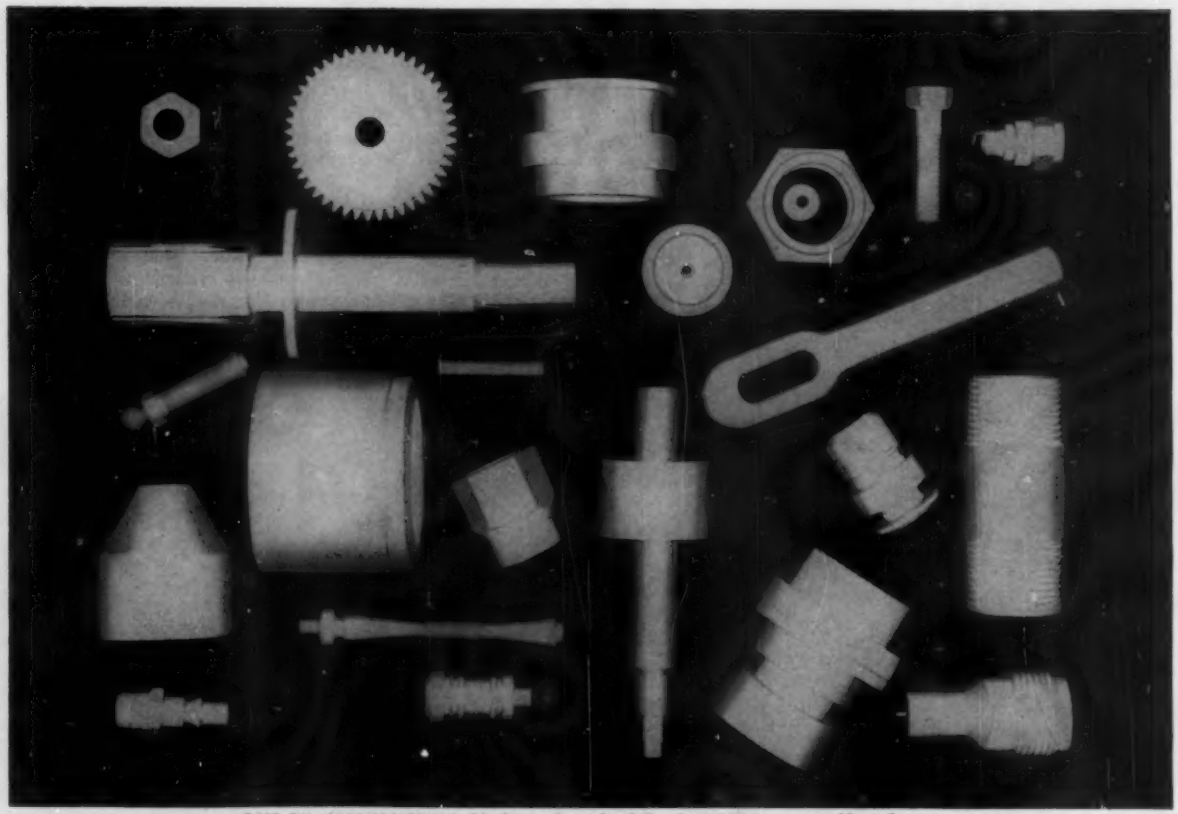

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is provided which is raised against the indenter by two vertical lead screws through a handwheel drive. The table will handle loads up to 550 lb. and accommodate work up to 27 in. below the indenter.

For further information circle No. 967 on literature request card, page 48-B.

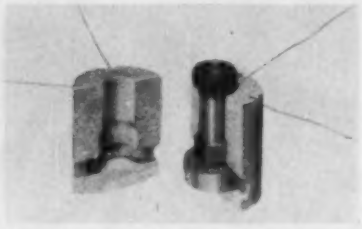
Recorder

A multiple-printing strip-chart telemeter receiver has just been announced by the Bristol Co. It will print up to 16 separate records from as many transmission centers. The variables need not be all of one kind, but could be a combination, such as pressure, flow, temperature and liquid level. The instrument prints on a 12¼ in. strip chart, and is available with either a 5 or 15-sec. time-impulse telemetering system.

For further information circle No. 968 on literature request card, page 48-B.

Heating Elements

Thermoshell electric heating elements have been announced by Cooley Electrical Mfg. Corp. Resistor wires are spaced in the element and heat it uniformly. The inside area of the element is placed in close contact with the surface of the pipe or valve to be heated. A recent application involved the heating of a sodium valve on a line carrying high-temperature sodium. In this case a special ceramic shell was designed and molded to withstand high temperatures. This thermoshell is pictured.



For further information circle No. 969 on literature request card, page 48-B.

Induction Heating

Robotron Corp. has announced a full line of induction heating units. The equipment is available in three frequency ranges: low frequency, 7½ to 1750 kw., 1 to 10 kc., motor generator powered; medium frequency, 3 to 50 kw., 450 kc., electronic generator equipped; and high frequency, ¾ to 20 kw., 27.1 megacycles, electronic generator equipped. Units may be used for heat treating, hardening, billet preheating, ingot breakdown and joining operations including brazing and soldering.

For further information circle No. 970 on literature request card, page 48-B.

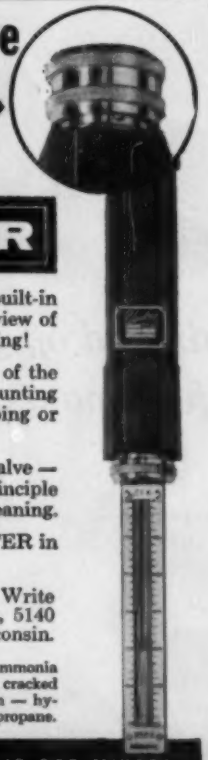
Electric Furnace

The Pereny Equipment Co. has announced a new vertical, 5000° F. elec-

the meter with the built-in Valve...

Waukee

FLO·METER



With the Waukee FLO-METER'S built-in Valve, you adjust the gas flow in full view of the scale. You can see what you're doing!

The Control Valve is an integral part of the FLO-METER, designed for panel mounting and simple piping. No extra valve piping or installation. Saves time and money.

It's a Waukee-designed and built valve — sturdy, simple, smooth. Needle-valve principle for accuracy, sensitivity, and easy cleaning.

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For measuring: air — ammonia — dissociated ammonia — argon — butane — city gas — endothermic cracked — exothermic cracked — forming gas — helium — hydrogen — natural gas — nitrogen — oxygen — propane.

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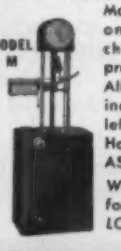
Whether you are working with metal, plastics, wire, rubber, springs, etc., an inexpensive DILLON Tester will make *hundreds* of accurate checks daily in your shop. Universal! Operates in tensile, compression, transverse or shear. Handles round, flat or special shapes. Two different machines – Model M for low strength materials between 0 and 300 lbs., and Model L for materials up to 125,000 lbs. PSI tensile. Hand wheel operated or motorized. Wide range of gripping fixtures.



Model L at right shown on stand. 7 interchangeable gauges provide wide range. All equipped with max. indicator. Model M at left is pendulum type. Has 5 scales. Meets ASTM & Fed. specs.

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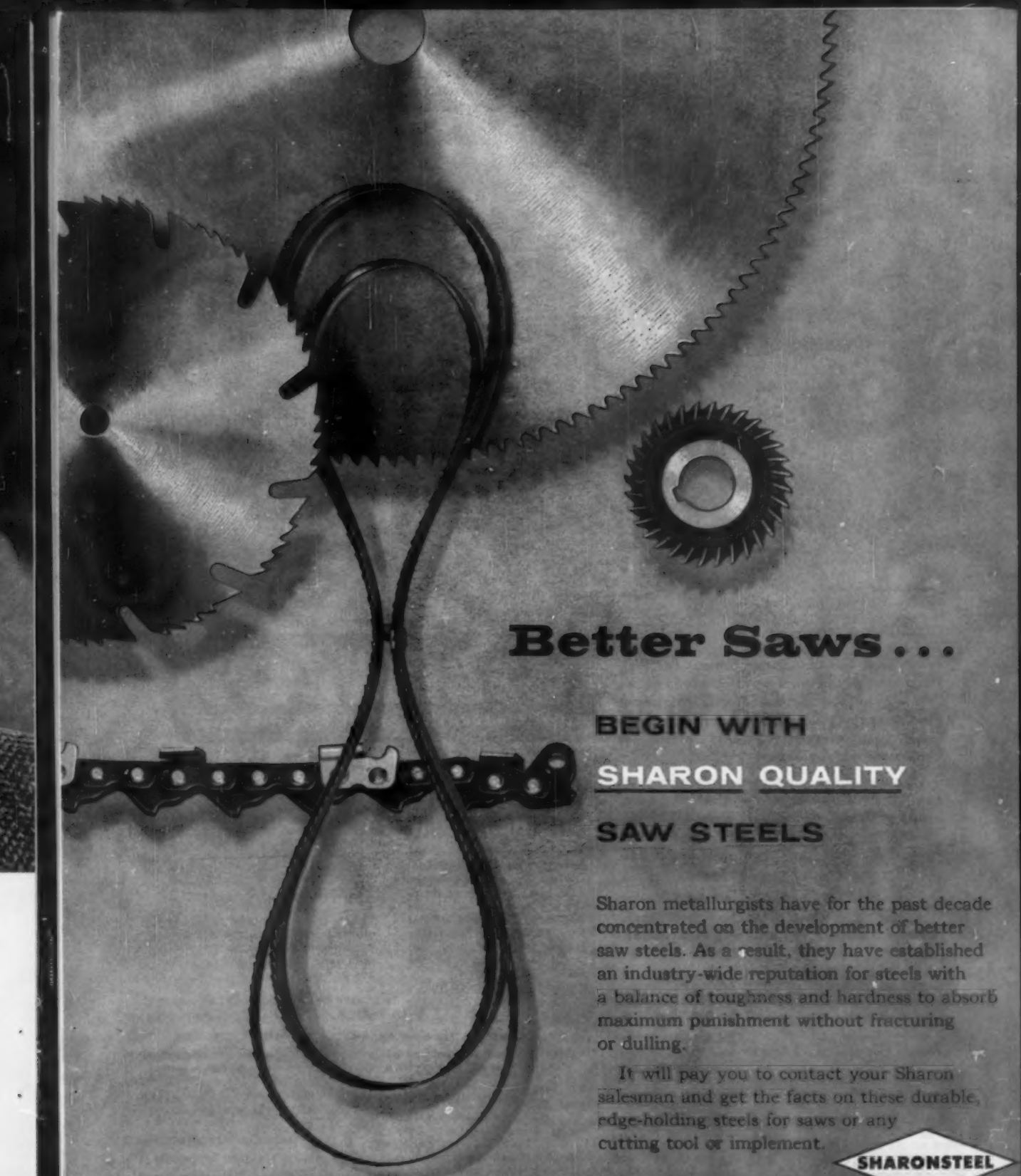

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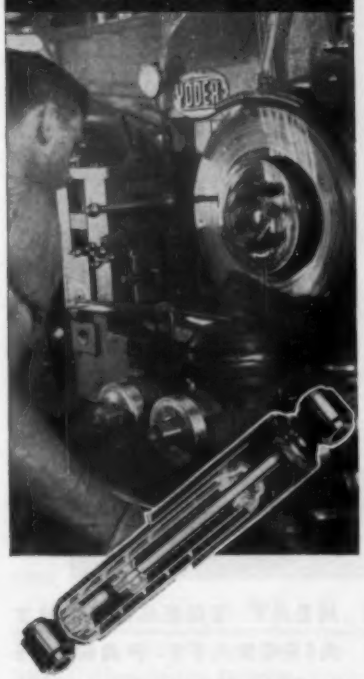
Monroe Shock Absorbers rely on Precision Performance of YODER TUBE MILLS



After 15 years of continuous operation the Yoder Type-M Electric-Resistance Weld Tube Mill shown here, is still producing precision tubing for the Monroe Auto Equipment Co., Monroe, Michigan.

Yoder produced tubing is the basic component of the famous "Monro-Matic" shock absorber. Measuring 2 1/64" outside diameter (plus several other sizes) the tubing is made from 22 gauge strip in one continuous operation . . . it is automatically cold-roll formed, welded and cut to pre-determined lengths.

This typical installation of a Yoder tube mill exemplifies the accuracy, dependability and production economies of Yoder-made tubing. If your business requires pipe or tubing, ferrous or non-ferrous, in sizes from 1/4" to 26" diameters, there is a Yoder mill designed to produce it economically, efficiently and accurately.

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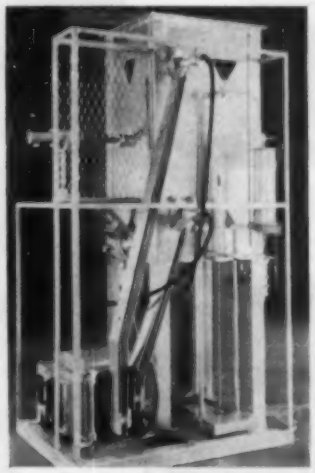
PIPE AND TUBE MILLS
(ferrous or non-ferrous)

tric furnace. The work load is raised or lowered hydraulically and the rate of movement can be controlled. The case is of all-welded steel, with a removable top. Electrodes and transformer are water cooled. Carbon resistor tube is positioned by graphite electrode blocks laid in refractory insulating brick within the transite liner. Tubes 2, 3 or 4 in. i.d. and 12 in. long have maximum connected loads of 30, 50 and 75 kw., respectively. Overall size of vertical model is 35 by 45 by 86 in.



For further information circle No. 971 on literature request card, page 48-B.

Lubricant

A lubricant and rust preventive that prevents metal-to-metal contact, eliminates or reduces stickers and toxic fumes and stays on the metal has been announced by Harry Miller Corp. for use in die casting, forging, drawing, and stamping. It remains on surfaces at temperatures up to 3000° F. and may be removed by using plain water, alkali solutions or solvents.

For further information circle No. 972 on literature request card, page 48-B.

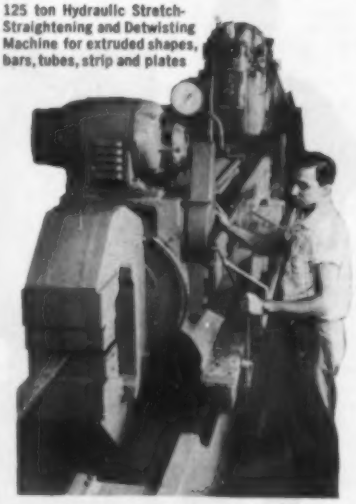
Atmosphere Furnaces

A new line of gas-fired hydrogen atmosphere furnaces, with heating chambers up to 14 by 48 by 10 in., has been announced by Eclipse Fuel Engineering Co. These furnaces with full Inconel muffles are built for maximum operating temperatures of 2100° F. Other types of muffles are available for temperatures to 2300° F. In the unit illustrated, work is pushed through the system manually; however, power pushers are available. Purge chambers at the entrance and exit of the system have flame-curtained doors.

For further information circle No. 973 on literature request card, page 48-B.

LOMA

125 ton Hydraulic Stretch-Straightening and Detwisting Machine for extruded shapes, bars, tubes, strip and plates



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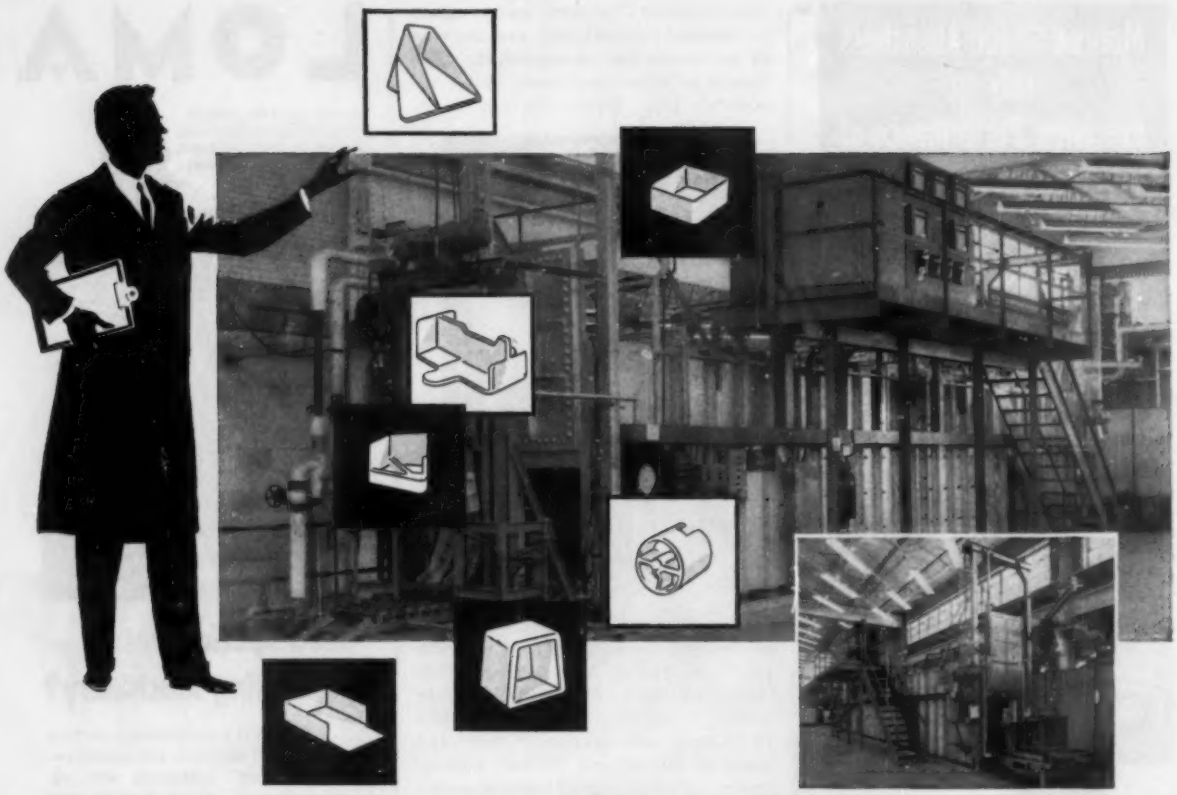

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C. I. Hayes electric fired equipment maintains Prex Corp's high quality standards at high production rates . . . provides the three essentials for solution heat treatment of aluminum (U.S.A.F. Specs.):

- **optimum temperature control**
- **complete freedom from products of combustion**
- **high speed, automated transfer from heat to quench**

Prex Corp., of Franklin Park, Illinois, pioneers in the production of No Draft Precision PRess EXtruded Forgings of aluminum alloy aircraft parts, uses this Type LA-406 Hayes Electric Furnace to solution heat-treat intricate, close-tolerance forgings.

Their process requires that large aluminum forgings be solution heat-treated at closely held temperatures between 750° to 950° F. The C. I. Hayes electric fired furnace holds temperature well within the ±10° F allowable variation . . . and totally avoids products of combustion which might cause high temperature oxidation.

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Investigate the many advantages of "push-button" heat treating today! You can reduce labor costs and spoilage . . . speed up production . . . and be assured of "RESULTS GUARANTEED"! Write today!

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☐ Carbo-Nitriding	☐ Copper Brazing and Soldering
☐ Tempering	☐ Lead Pot Hardening and Tempering
☐ Vacuum Heat Treating	☐ Atmosphere Equipment
☐ Bright Heat Treating	☐ Other

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APPLICATION and EQUIPMENT new literature

975. Abrasive Cleaning
Folder on Malleabrasive for airless blast cleaning equipment gives advantages, grades, equipment it can be used with and parts that can be cleaned. *Globe Steel Abrasives*

976. Abrasive Cleaning
Catalog 57-WX on brush types, sizes, speeds, filaments. Aids to power brush selection. *Pittsburgh Plate Glass*

977. Adhesives
New Technical Bulletin RTB-10A-1 on structural adhesives. Characteristics, properties. *H. B. Fuller Co.*

978. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

979. Alloy Steel
208-page book gives more than 50 complete case histories of alloy steel usage. *Climax Molybdenum Div.*

980. Alloys
New 8-page pocket-size Booklet No. J4 on low-melting temperature alloys. 62 applications in the metal field. Descriptions and physical properties. *Cerro de Pasco*

981. Aluminum Bronze
8-page booklet on study that led to development of one-piece, nickel-aluminum bronze ship propeller. *International Nickel Co.*

982. Aluminum Extrusions
Catalog of stock extrusion dies. *Jarl Extrusions*

983. Aluminum Finish
New Bulletin 1424-A on protective and prepaint coating chemicals for aluminum. Describes different types of Alodine. *American Chemical Paint*

984. Aluminum Finishing
Bulletin F9881 on process for applying conversion coating to aluminum and zinc. *Oakite*

985. Atmosphere Control
New 8-page Bulletin SC-178 on furnaces, atmosphere equipment, controls for bright annealing, hardening and tempering, batch annealing, age hardening and carburizing. *Surface Combustion*

986. Atmosphere Furnace
Bulletin on controlled atmosphere furnace. *Industrial Heating Equipment*

987. Belting
New 6-page Bulletin MF-600 on hinged steel belting. 6 inches to 6 feet in width, any length or capacity required. *May-Fran Engineering*

988. Beryllium
New 24-page booklet on beryllium. Graphs and charts with up-to-date facts on properties. *Brush Beryllium*

989. Blast Cleaning
Bulletin No. 703 gives complete specifications and dimensions of Blastmaster barrels from 1.5 cu. ft. to 27 cu. ft. Automatic operation. *Pangborn*

990. Brazing
16-page pocket-sized guide to selective fluxing for low-temperature silver brazing. *American Platinum*

991. Brazing
16-page reprint on furnace brazing gives advantages of method, design factors and methods of handling assemblies and furnaces for brazing. *Electric Furnace*

992. Brazing
New Bulletin 17 on low-temperature silver alloy brazing. *Handy & Harman*

993. Bronze
Folder gives tables of properties, uses, forms and other data on phosphor bronzes. *Chase Brass*

994. Bronze Bearings
12-page bulletin on Promet bronze bushings, bearings, bar stock and babbitt metal. Technical data. Case histories. *American Crucible Products*

995. Buffing and Polishing
24-page catalog on cutting, coloring and double duty compounds for 12 metals, plastics and rubber. *Hanson-Van Winkle-Munning*

996. Carbides
New 24-page booklet on production of tungsten carbide products by both the hot and cold press method. *Metal Carbides*

997. Carbon Brick
Bulletin on properties, grades, applications of carbon and graphite brick for handling corrosive chemicals and molten metals. *National Carbon*

998. Carbon & Dew-Point Control
New Bulletin DC-58 on Carbotronik and Dewtronik for control of carbon potential and dew point in atmospheres. *Ipsen*

999. Carbonitriding
Literature on Ni-Carb (carbonitriding) treatment for surface hardening. *American Gas Furnace*

1000. Castings
Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*

1001. Centrifugal Castings
8-page brochure gives properties of most common grades of thermalloy centrifugally cast tube. Weight tables. *Electro-Alloys Div.*

1002. Chemicals
22-page bulletin on industrial chemicals lists those available and illustrates their manufacture and testing. *Harshaw Scientific*

1003. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

1004. Chromium Plating
Bulletin CFC-1 on advantages of crack-free chromium plating process. *Metal & Thermit*

1005. Chromizing Process
8-page bulletin on corrosion resistance of chromallized iron and steel. *Chromalloy*

1006. Cleaners
4-page bulletin No. E-1 on five cleaners for power washers, soak tanks, electrolytic cleaning, emulsion cleaning. *Park Chemical*

1007. Cleaning Aluminum
12-page bulletin on cleaning process for preparing aluminum and magnesium for welding. *Northwest Chemical*

1008. Coated Metals
New bulletin on roll coating shows how it is done and includes samples. *Roll Coater, Inc.*

1009. Cold Rolled Steels
New 48-page Handbook MS-158 on roller die, cold forming metal shapes. Material selection, specifications. *Van Huffel Tube Corp.*

1010. Compressors
12-page data book 107-D gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

1011. Controller
New 6-page Bulletin No. 3885 on Pyrotroller, an indicating-controlling pyrometer. Design, specification, applications. *Illinois Testing Lab.*

1012. Controls
New Bulletin AC-3 on eleven electromechanical controls for industrial applications. *Tipptronic, Inc.*

1013. Copper Alloys
36-page catalog on phosphor bronzes, nickel silvers, beryllium copper, cupronickel. Chemical and physical data. Engineering tables. *Riverside-Alloy Metal*

1014. Copper Foil
New 8-page Publication D-8 on copper foil, available in three grades, many thicknesses. Applications. *American Brass*

1015. Creep Tester
Bulletin on new creep rupture tester designed for laboratory testing of small specimens. *Arcweld Mfg.*

1016. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

1017. Degreasing
40-page book on trichlorethylene gives specifications, properties, uses, handling and storage, toxicity and safety measures. *Hooker Electrochemical Co.*

1018. Descaling Process
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *DuPont*

1019. Drawing Dies
12-page bulletin on turks head, adjustable draw die. Basic types, development of turks head, various types. *Fenn Mfg.*

1020. Ductile Iron
New 12-page Bulletin MPC provides data on application of ductile iron for machine parts. Material specifications. *Cooper-Bessemer*

1021. Electric Furnace
Bulletin on box-type, pre-heat and hardening furnace with automatic atmosphere contamination control. *Pacific Scientific*

1022. Electric Furnaces
Catalog on electric furnaces and ovens for hardening, tempering, annealing, drawing, drying, baking, enameling. *Cooley Electric Mfg.*

1023. Electric Furnaces
8-page Bulletin 570 on heat treating,

ACHESON

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Reporting uses for

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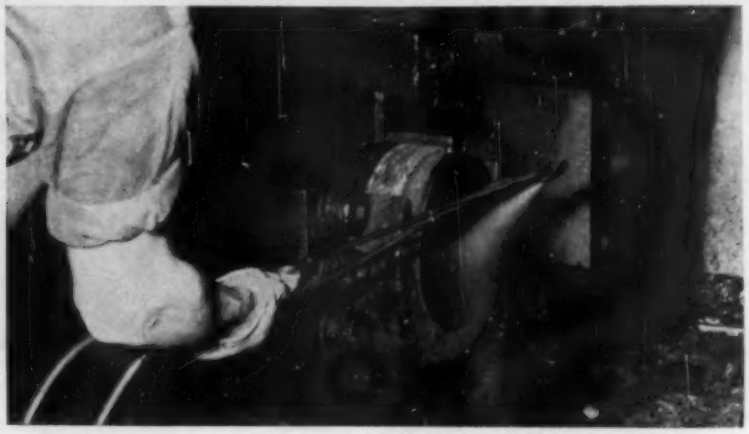
COLLOIDAL GRAPHITE, MOLY-SULFIDE, VERMICULITE, AND OTHER SOLIDS

WHY 'DAG' DISPERSIONS MEAN *PERFORMANCE* IN ALUMINUM EXTRUDING

The excellent lubricating properties of Acheson Colloidal Graphite, under conditions of extreme heat and pressure have been confirmed by leading extruders of aluminum, steel, copper, brass, lead and other metals. Water-base dispersions of colloidal graphite used in the following application histories have provided savings in material handling, reduced maintenance time and expense, prevented seizure, extended die life, and produced extrusions of more uniformly high quality. Any one of these benefits should make profitable reading for you.



For faster, more uniform application with less material consumption, Aluminum Extrusions, Inc. finds 'Aquadag' their best die lubricant.

A little 'Aquadag' goes a long way for Aluminum Extrusions, Inc., Charlotte, Michigan. This company, one of the leading independent extruders in the country, has found that by applying 'Aquadag' on die surfaces they have effected a 30% savings in their material handling. Formerly, they had used an oil-graphite mixture which required a dilution ratio of 16 lbs. of graphite to a 55 gallon drum of oil. It was too slowly applied by swab and too coarse to apply by spray with any degree of efficiency.

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Considered in relation to the over 12 million pounds of aluminum extruded yearly at this plant . . . 85% of it in fabricated form . . . *'Aquadag' has brought important production efficiencies and material economy* to Aluminum Extrusions, Inc. In many, similar instances where product quality and basic economy are demanded, Acheson colloidal dispersions have gained ready acceptance.

Exclusive Acheson processing techniques guarantee a consistently uniform top-quality product. If your problem is more effective lubrication under normally adverse conditions of extreme temperature, pressures, or abrasion, call in your Acheson Service Engineer.

Dies last three times longer with 'Aquadag', according to another prominent midwest extruder. Metal pickup on the extruding dies has been completely eliminated by the use of this Acheson dispersion, extending the effective use of the dies from 1000 to 3000 strokes. The evaporation of its water-base leaves a dry, adherent "graphoid" film on all lubricated surfaces, inhibiting the build-up of abrasive precipitates. At the same time, the unbroken, microscopically-thin film that 'Aquadag' provides, facilitates metal flow and reduces scoring to a negligible minimum. Application of the lubricant is by spraying a dilution of 1 part 'Aquadag' to 20 parts water, on the die surface before each "push" of the extrusion press.

A 'dag' graphite coating is also applied to the follow blocks on this company's 1400 ton horizontal extrusion presses. For purposes of even greater economy, 'Prodag' — semi-colloidal graphite in water — is used in this application. This effective parting agent prevents the flash, back-extruded from the billet skin, from locking the butt to the follow block. An Acheson dispersion is very possibly the answer to your lubricating troubles. For additional information, write for your free copy of Bulletin 426. Address Dept. MP-48.

Extended die life and extrusions with more perfect surface finish, are attributed to the use of 'Aquadag'.

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melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Perenv*

1024. Electrochemicals
New 16-page booklet gives physical properties of 23 electrochemicals including silicon carbide, zirconium oxide and borides. *Norton Co.*

1025. Extensometer
8-page bulletin on extensometers for sheet metal and wire, compressometers, deflectometers and other accessories. *Baldwin-Lima-Hamilton*

1026. Extrusions
Bulletin on extruded seamless alloy and stainless steel tubing. Properties, shapes. *Metals Processing Div., Curtiss-Wright*

1027. Electron Microscope
24-page booklet on use of electron microscope in science and industry. *RCA*

1028. Finishing
New bulletin describes final-finishing of new forging dies. Cleaning and refinishing used forging dies. *Vapor Blast Mfg. Co.*

1029. Finishing Systems
New 8-page Catalog No. 600 on cleaning, painting and baking equipment. 17 isometric drawings. *Schmieg Industries*

1030. Flow Meters
Bulletin 203 on flow meter for gas used in heat treating. *Waukee Eng'g.*

1031. Forgings
Bulletin on forge steelmaking, open die forging, machining, heat treating and finishing. *National Forge*

1032. Forgings
Folder on facilities for production of flat-die forged products. Electronic equipment used. *Smith-Armstrong*

1033. Forgings
12-page booklet on how forged weldless rings and flanges are made. Case histories. *Standard Steel Works Div., B-L-H*

1034. Formed Plate
Bulletin on stainless steel flanged heads. 246 available dies listed. *G. O. Carlson*

1035. Formed Shapes
26-page Catalog No. 1555 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

1036. Forming
New 88-page book on equipment and process of cold roll-forming. Wide sheets, narrow trim, tubular shapes, curving, coiling, tooling needed. *Yoder*

1037. Freezer
Data on chest for use down to —95° F. for production use and testing. *Revco*

1038. Freezers
Data on industrial freezers for cold treatment of metals. *Harris Refrigeration*

1039. Furnace
New Bulletin No. 471 on combination hardening and tempering furnace. *C. I. Hayes, Inc.*

1040. Furnace
New bulletin on basic principles of electric furnace design. Cutaway models of 8 furnaces. Cost factors. *Holcroft*

1041. Furnaces
Bulletin No. HT-53 on high-temperature furnaces for temperatures up to 2000° F. *Carl-Mayer*

1042. Furnaces
16-page bulletin 135 on industrial furnaces and atmosphere generators. Continuous systems. *Continental Industrial Engineers*

1043. Furnaces
6-page bulletin on recirculating furnaces. Solution heat treating of aluminum alloys, conveyorized ovens, batch-type and car-bottom furnaces. *Despatch Oven*

1044. Furnaces
Bulletin describes 18 electric furnaces for research and small-scale production, with operating temperatures to 3000° F. *Harper Electric*

1045. Furnaces
Lists of surplus furnaces for sale. *Joe Martin Co.*

1046. Furnaces
32-page catalog of industrial equipment includes furnaces and furnace accessories, special valves, mechanical equipment, materials handling equipment. *Salem-Brosius*

1047. Furnaces
Folder describes complete set-up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

1048. Furnaces
Bulletin on radivection furnaces with radiant heat and forced convection. Advantages. *A. F. Holden*

1049. Gas Generator
Bulletin 157 on endothermic generator. Operation, special features and specifications given. *Hevi Duty*

1050. Gas Welding
36-page Catalog 160 on applications of oxyncetylene welding and cutting torches and accessories. *Modern Engineering*

1051. Graphite
6-page revised bulletin No. 435 on colloidal graphite for surface coatings and impregnation. *Acheson Colloids*

1052. Graphite
Folder on graphite crucibles, funnels, and special preformed electrodes. High-purity powder. *United Carbon Products*

1053. Hard Surfacing
New 20-page Booklet No. HS-127 on hard surfacing electrodes and wires. Classifications, properties, applications of each. *McKay Co.*

1054. Hardening Tool Steels
4-page bulletin on complete line of hydryzing furnaces. Diagrams, specifications and performance data on preheat and high speed furnaces. *Lindberg Engineering*

1055. Hardness Numbers
Pocket-size table of Brinell hardness numbers. *Steel City Testing Machines*

1056. Hardness Tester
New Bulletin F-1689-3 on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman Co.*

1057. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1058. Hardness Tester
Bulletin on how to test large gears with portable Brinell tester. *King Tester*

1059. Hardness Tester
4-page bulletin on portable metal hardness tester for any shape or metal. Ranges, features. *Newage Industries*

1060. Hardness Tester
Catalog 72-1 on Leitz miniload tester for Vickers and Knoop hardness tests. *Opto-Metric Tools, Inc.*

1061. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

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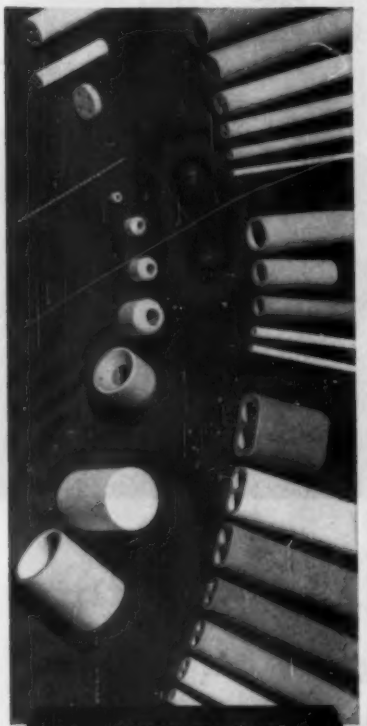

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1062. Hardness Tester
4-page bulletin on tester for both superficial and regular hardness testing. *Torsion Balance Co.*

1063. Hardness Testers
New 20-page Catalog No. DH-326 on models, applications and how to use superficial hardness testers. *Wilson Mechanical Instrument Div.*

1064. Hardness Testing
Bulletin A-18 on Alpha Co. Brinell hardness testing machines. *Gries Industries*

1065. Heat-Resistant Alloys
Catalog and stock list of sheets, plates and bars of heat-resistant alloys. *Rolled Alloys, Inc.*

1066. Heat Treat Pots
Catalog on pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. *Eclipse Industrial Combustion Div.*

1067. Heat Treating
New 8-page bulletin on heat treating. Data sheets on processes and processing equipment. Also covers annealing, brazing and hardening. *Ferrotherm*

1068. Heat Treating
Catalog of complete line of heat treating furnaces and atmosphere generators, electric and fuel-fired. *Sargeant & Wilbur*

1069. Heat Treating
Bulletin describes baskets, crates, trays, furnace parts for heat treating. *Stanwood*

1070. Heat Treating
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

1071. Heat Treating
4-page folder gives description of home study course on "Heat Treatment of Steel" offered by the ASM Metals Engineering Institute. *Metal Progress*

1072. Heat Treating Belts
Catalog of conveyor belts and data for their design, application and selection. *Ashworth Bros.*

1073. Heat Treating Fixtures
4-page folder on retorts, baskets, trays, carburizing boxes, fans for heat treating. *Aluminum & Architectural Metals Co.*

1074. Heat Treating Fixtures
32-page catalog G-10A lists process equipment, heavy welded fabrications, muffles, trays, fixtures for furnaces, heat-treating equipment, pickling equipment. *Rolock*

1075. Heat Treating Furnaces
Folder on industrial furnaces. Continuous designs. Insulation. *Pacific Industrial*

1076. Heaters
Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

1077. Heating Elements
24-page booklet on elements for electric furnaces and kilns includes technical data, uses, physical and electrical specifications. *Norton*

1078. High-Strength Steel
26-page booklet on properties, uses, applications of high-tensile low-alloy steel. *Jones & Laughlin*

1079. High-Temperature Castings
16-page manual on heat and corrosion resisting castings. Principles of alloy composition, their properties and limitations, stabilizing influences and heat treatment. *Michigan Standard Alloy*

1080. Hydraulic Tables
New 40-page Bulletin No. 3300 on presses and applications. 28 pages of tables

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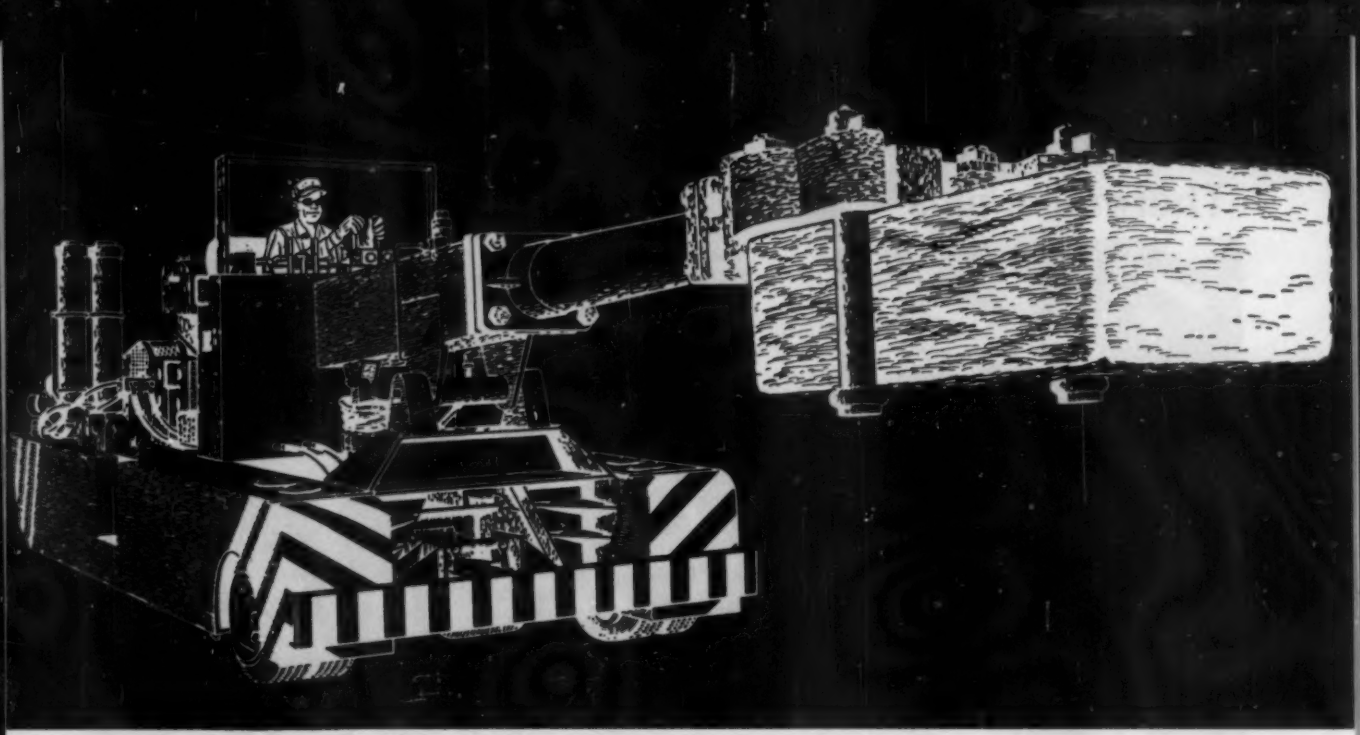

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For maximum efficiency and flexibility in furnace operations, load and unload your heating furnaces and charge your melting furnaces with a Salem-Brosius Auto-Floor Charging Machine. One man at the controls operates this agile piece of equipment, serving furnaces faster and with greater all-around economy than is possible with any other stock-handling equipment.

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Initial cost of the Salem-Brosius Charging Machine is far less than other types of charging equipment. It has saved as much as 75% in operational costs, replacing several men of a furnace crew. It eliminates costly maintenance of elaborate materials handling equipment, while requiring a minimum of maintenance itself.

Before you invest in expensive stock-handling equipment, investigate the Salem-Brosius Auto-Floor Charging Machine—designed and built by men who know your stock-handling problems.

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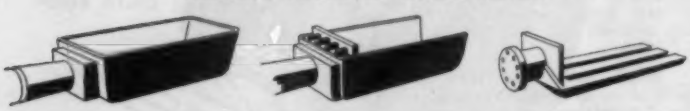
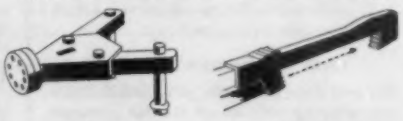


Rotating Box | Pusher Box | Pusher Fork

HEATING FURNACE WORK HEADS



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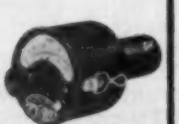

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CO., INC.
BERGENFIELD 8, NEW JERSEY

on decimal equivalents, hydraulic ram capacities, wire and sheet metal gages, strength of material, etc. *Hamilton Div., B-L-H*

1081. Induction Heating
Folder 15C8053C gives advantages of induction heating and specifications and dimensions of induction heater. *Allis-Chalmers*

1082. Induction Heating
12-page bulletin gives descriptions, technical data on various sizes. Water systems diagrammed, and standard accessory equipment. *High Frequency Heating Div., Lindberg Engineering*

1083. Induction Heating
60-page catalog tells of reduced costs and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

1084. Induction Melting
New Folder R-51 on line frequency induction melting furnaces in modern zinc and aluminum die casting plant. *Ajax Engineering Corp.*

1085. Inspection
New 6-page bulletin on micro-projector. Small intricate parts can be rapidly and accurately inspected for size, form and finish. *Geo. Scherr*

1086. Instruments
6-page Bulletin 11-E on mechanical force gage for measuring pressure, tensile or torque. *W. C. Dillon*

1087. Insulating Firebrick
8-page bulletin R-43 gives description of relationship between heat losses and weight of refractory lining. *Babcock & Wilcox, Refractories Div.*

1088. Isothermal Quenching
Bulletin dealing with isothermal treatment of carbon and alloy steel in molten salt baths. *Ajax Electric*

1089. Laboratory Furnace
Data on nonmetallic resistor furnaces for research, testing or small-scale production. *Harrop Electric Furnace*

1090. Laboratory Furnaces
Bulletin 1016 on single and dual tube furnaces for combustion analysis. *Sentry*

1091. Laboratory Furnaces
New Bulletin S-1055 on gas-fired laboratory furnaces which provide temperatures from 1000 to 3350° F. *Selas*

1092. Leaded Alloy Steel
8-page bulletin gives mechanical properties of Rycut 40, Medium-carbon fast machining leaded alloy steel. Case studies. *Ryerson*

1093. Leaded Steels
16-page booklet on basic characteristics, mechanical properties and workability of leaded steels. Case histories. *Copperweld Steel Co.*

1094. Lubricants
8-page booklet on colloidal greases, forging compounds, hydraulic concentrate and others. *Grafo Colloids*

1095. Magnesium
New 53-page book on wrought forms of magnesium. Includes 44 tables. *White Metal Rolling & Stamping Corp.*

1096. Magnetic Alloys
Article on use of vanadium in magnetic alloys. Comparison of Supermendur and Permendur. Vancoram Review, Fall 1957. *Vanadium Corp.*

1097. Magnetic Materials
New 64-page book on electronic, magnetic and electrical alloys. Engineering properties and fabrication characteristics. *Carpenter Steel Co.*

1098. Marking
Data on hammers for metal markings. *Pannier Corp.*

1099. Marking Machines
Data on various types of marking ma-

(Continued on page 48-A)

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IRON
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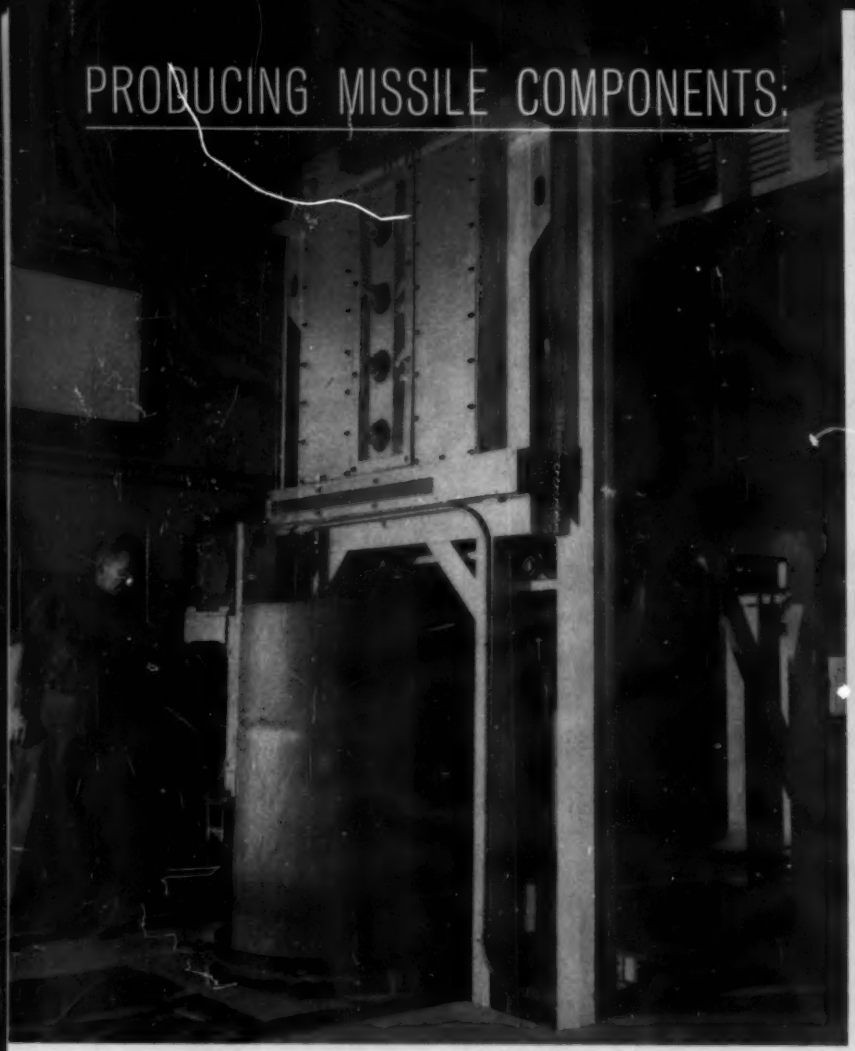

STAINLESS BRAZING PROBLEMS LICKED

By assembling inexpensively-produced components and then brazing them in this Harper Elevator Furnace, Fabriform Metal Products, Inc., Los Angeles, has by-passed high manufacturing costs. Forging, casting and excessive machining have been eliminated in producing a tremendous variety of complicated products . . . including stainless missile and jet engine parts.

Operated on a two-shift basis, the Harper Furnace has not only proved extremely versatile, but has enabled Fabriform to overcome many tough brazing problems. Even metal working dies and molds of tool steel have been copper brazed without decarburization. Recently, a thousand stainless steel bearing housings were copper brazed with only one reject in the lot. Relatively heavy sections of difficult-to-braze super alloys such as A-286 and Inconel X have been handled successfully. Excellent results have been obtained using a variety of base metals, as well as filler metals including nickel-base alloys.

With the furnace capable of holding a ton of parts stacked 30″ high within a 24″ diameter, temperatures up to 2100 F can be attained in the inconel retort. Temperature uniformity is excellent: Placed within loads 20″ high, matched thermocouples show no temperature differences.

"The Harper Furnace is extremely flexible and can produce practically any time-temperature cycle within reason," says A. M. Thompson, Gen. Mgr. of Fabriform. "Because we can hold effluent dew points of —90 F, it's possible to do extremely difficult jobs . . . We haven't had a forced shutdown since installation over three years ago."

To reap the maximum benefits of furnace brazing, you'll find it pays to talk to a Harper representative . . . for Harper can build the furnace best suited to your needs: box, pusher, mesh belt, roller hearth, bell, elevator or pit. For detailed information, write: Harper Electric Furnace Corp., 40 River St., Buffalo 2, N. Y.

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FOR BRAZING, SINTERING, WIRE ANNEALING, BRIGHT ANNEALING, FORGING AND RESEARCH

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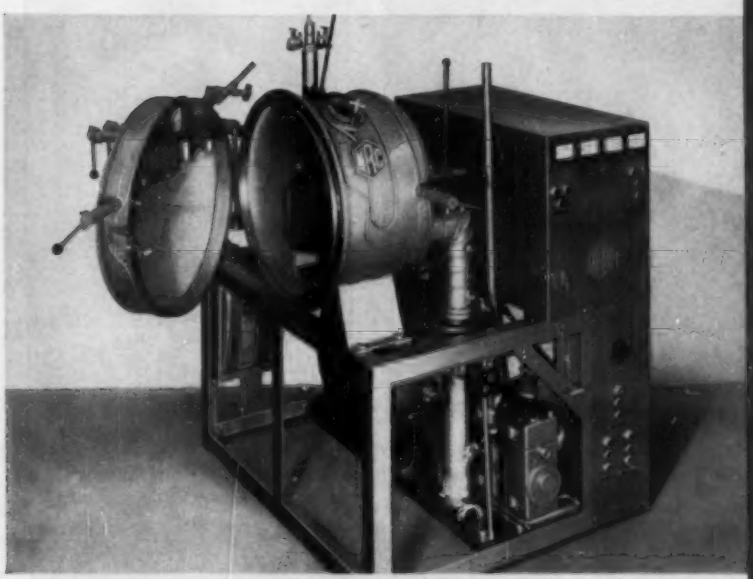
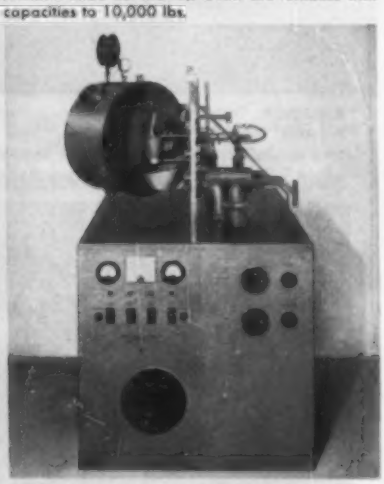
NRC experience and standard ARC, INDUCTION and RESISTANCE furnaces can remove the mystery from vacuum metallurgy



NRC Model 2351 Vacuum INDUCTION Furnace. Packaged facility for melting, purifying, alloying, casting and heat treating. Capacity 12 lbs. Other standard and special induction furnaces with capacities up to 5000 lbs.

NRC Model 2703 Vacuum ARC Furnace. Safe and versatile unit for consumable or nonconsumable electrode melting into cold mold or skull (consumable head not shown). Other arc furnaces with capacities to 10,000 lbs.



NRC Model 2904-B Vacuum RESISTANCE Furnace. Over 100 now in use for melting, purifying, alloying, casting, sintering, brazing, annealing, and heat treating. Capacity 2-8 lbs. Temperature above 2000°C. Pressures to 10^{-5} mm Hg. Other standard resistance bell, muffle, and pit furnaces with hot zones to 54" dia. by 12'.

If you're considering vacuum metallurgy as part of your product improvement or quality control program, you don't have to start from scratch. You can get a head-start by drawing on the experience NRC has gained from building and operating more high vacuum furnaces than any other organization in the world. You can easily find out

If vacuum metallurgy can help you as it has others.
Whether you really need to run your own development program.
What type of furnace would be most suitable for your program.
How to avoid the expensive pitfalls which have so often trapped beginners.

Then, if you decide to run your own development program, you'll find you can get started easily, economically and quickly with a standard NRC furnace, such as those shown here. You won't need a vacuum expert to run it either. NRC furnaces are designed for simplicity, and our engineers will teach you up-to-date operating techniques. This is the way for you to get useful results sooner, with a minimum investment in equipment, time, and operating costs.

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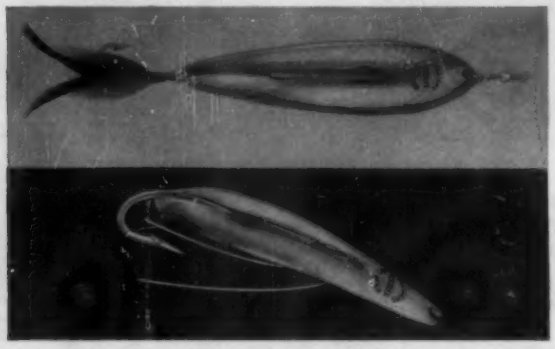
NEW BRASS CUTS POLISHING COST

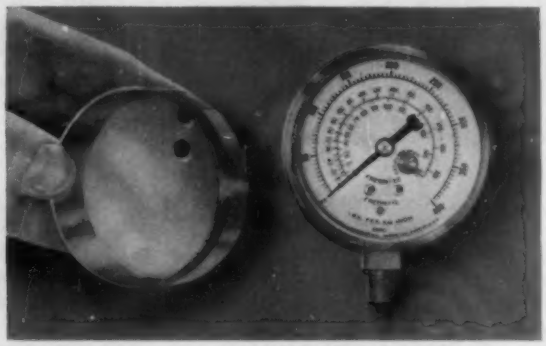
also gives you clean, easy drawing and forming, plus higher physical properties—Formbrite,® Superfine-Grain Drawing Brass by Anaconda

AIRGUIDE Instrument Co., Chicago, gets high luster finish on bezels for its famous weather instruments at 50% lower cost since it switched from ordinary drawing brass to Formbrite. Airguide does the presswork—says Formbrite "draws and forms excellently." Driscoll & Co. (above) polishes the bezels.

BAROMETER in Chippendale style, "Mayfair," is one of the broad line of brass-trimmed instruments made for home and marine use by Airguide.



FISHING LURES made by Williams Gold Refining Co., Inc.—"Wabler," top and "Weedler," below—are polished for plating by tumbling. Switching from ordinary yellow brass to Formbrite cut costs more than 40%.



MARSH Instrument Co., Skokie, Ill., dropped a finishing operation and gets a "mirror finish" with a light buff, by using Formbrite. Marsh reports that finishing cost was cut 40% and that forming is "excellent."

Wherever finishing is an important cost factor in formed or drawn products, Formbrite in sheet and strip is designed to save you money. In brass wire alloys for cold-heading and upsetting, it gives a stronger, springier, more abrasion-resistant product. For more detailed information, write for Publication B-39. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

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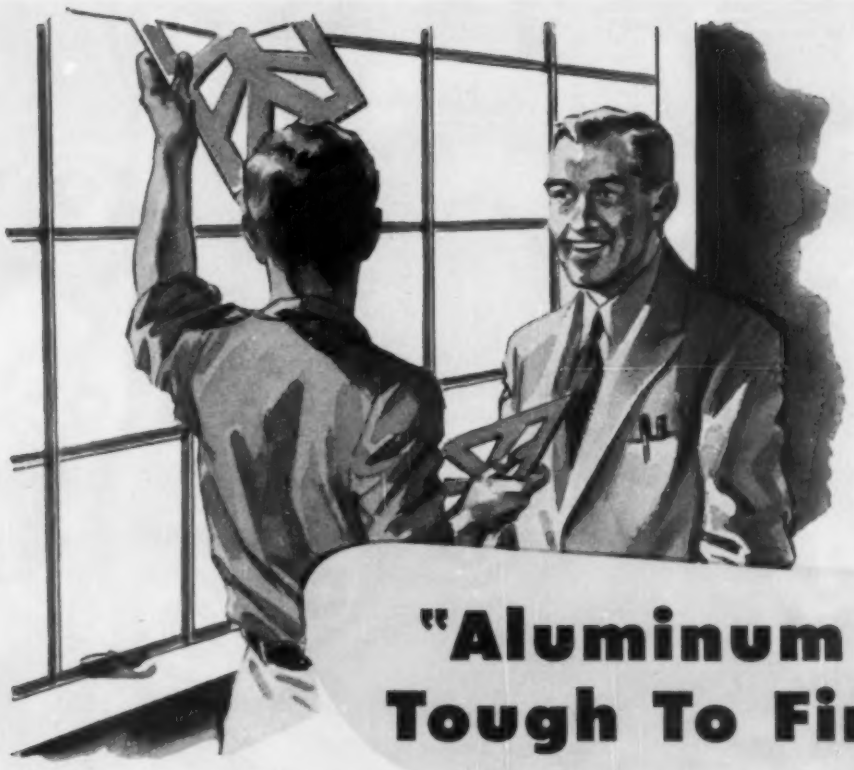

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. . . before Northwest developed these SPECIAL ALUMINUM CHEMICALS."

If you work with aluminum you'll be interested in Northwest's outstanding line of chemicals for use with modern alloys. Northwest's continuing research and development program has earned them the reputation of "First with the best" in this rapidly developing field. It will pay you to investigate:

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Let our Cleaning Specialists help you!

- **ALKALUME CLEANERS**—A full line of cleaners and etching compounds especially formulated for use on aluminum alloys prior to plating, anodizing, painting or welding.
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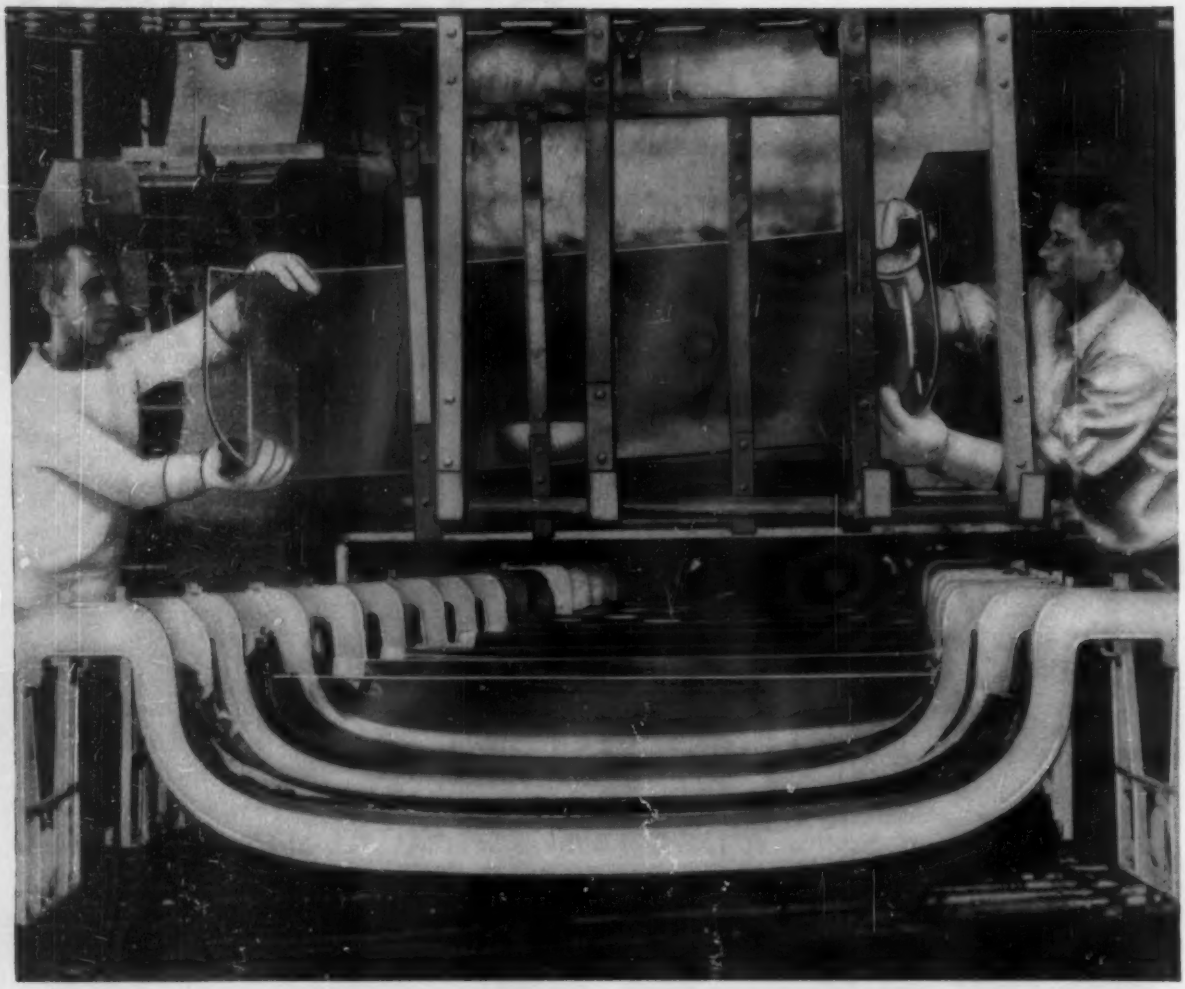
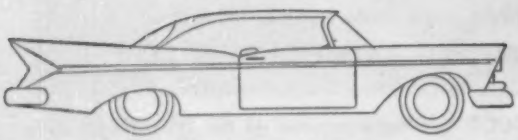


Greater visibility, trimmer lines in new car styling... thanks to GAS



With nearly 7,000,000 cars being produced annually, the increased use of glass has demanded major production improvements in the manufacture of new panoramic windshields and back-lights.

Since the forming of the intricately curved glass is done at a temperature at which glass is soft and can be bent, the production process challenged heat process engineers to design new automatic equipment capable of mass producing these large precision glass pieces.

Selas engineers, working with the nation's leading glass manufacturer, discovered that Gas could produce the proper time-temperature cycle demanded by this process, efficiently, quickly, reliably. The flat glass is conveyed under radiant Gas burners which bring the glass quickly up to bending temperature and allow the shaping of windshields, with reproducible uniformity, at high production rates.

The production of this wrap-around windshield is another example of the contributions modern Gas equipment is making to American manufacturing. If you have an operation demanding precise process heating, call your local Gas Company's Industrial Specialist and discuss the economies and results you, too, can get with modern Gas equipment. *American Gas Association.*

See Playhouse 90 with Julie Meade on CBS-TV. Watch local listings for time and station. Sponsored by your Gas Company and the Gas Industry.

(Continued from page 43)

chines from bench mounted machines for light duty marking to machines capable of marking at up to 6 tons table pressure. *Jas. H. Matthews & Co.*

1100. Melting
Articles on commercial vacuum furnaces for metals and alloys and some aspects of vacuum melted metals. *NRC Equipment*

1101. Metal Sorting
Data on nondestructive sorting tool for raw, semi-finished or finished parts. *J. W. Dice*

1102. Metal Treatment
Booklet on metal treating and finishing products. *John Swift Chemical Co.*

1103. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance*

1104. Microscopes
New 8-page Bulletin SB2200-1157 on metallurgical microscopes. Accessories. *American Optical*

1105. Microscopes
40-page catalog on metallographs, metallurgical, toolmakers, stereoscopic, polarizing, phase and other microscopes. *Unitron Instrument Div., United Scientific*

1106. Nickel Alloy
12-page booklet on Hastelloy Alloy R-235, vacuum-melted wrought alloy containing aluminum and titanium. *Haynes Stellite*

1107. Nickel Tubing
New 20-page catalog gives properties and compositions of 13 analyses of nickel and nickel alloy tubing. Selection guide. *Superior Tube*

1108. Nitrogen Generator
6-page Bulletin No. I-100 gives flow diagram and explains operation. *C. M. Kemp Mfg. Co.*

1109. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

1110. Ovens
New Bulletin No. 5720 on mechanical recirculating utility ovens with automatic temperature control. *Blue M Electric*

1111. Ovens
New Bulletin 4-257 on gas, oil and electric ovens. Load carrying door, electric drawer and walk-in type ovens. *Grieve-Hendry*

1112. Perforated Metals
4-page folder gives ordering specifications and patterns. *Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp.*

1113. Phosphor Bronze
Facilities for rolling, cleaning, welding, trimming and treating phosphor bronze. *Rolling Mill Div., Miller Co.*

1114. Plating Solutions
Operating manuals for plating with metal fluoborate solutions. *Baker & Adamson.* See page 4.

1115. Powder Press
New bulletin on 100 ton fully mechanical multi-action powder metal press for conventional punches and dies and withdrawal die sets. *Dorst Div., Arnhold Ceramics, Inc.*

1116. Powdered Iron
New 12-page Bulletin No. 2 on iron powders. Properties of Plast/Iron, Plast/-Steel, Plast/Nickel, Plast/Manganese and Plast/Silicon. *Plastic Metals Div.*

1117. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

1118. Presses
Data on mechanical and hydraulic powdered metal presses 8 to 500-ton capacities. *Haller, Inc.*

1119. Protecting Tubes
New bulletin 1000-56 on ceramic protecting tubes lists sizes and materials. *Claud S. Gordon*

1120. Protective Coatings
Folder 301 on industrial protective coatings of rubber, neoprene and other materials. *Arco Steel Fabricators*

1121. Pure Metals
New 20-page booklet on pure metals, master alloys and ferroalloys. Chemical analysis, powder mesh sizes, vacuum melting grades. *Shieldalloy*

1122. Pyrometers
New 8-page Catalog No. 175 on instruments for temperature measurements. Advantages, operating procedure, accessories. *Pyrometer Instrument Co.*

1123. Quenching
Catalog FR-853 on two small self-contained quenching units. *Bell & Gossett*

1124. Quenching Oil
New folder on quenching oil. Five tables. *E. F. Houghton*

1125. Quenching Oil
Bulletin 37 on light quenching oil. Effect of agitation on quenching speed. *Sun Oil*

1126. Radiation Badges
Data on badges which record exposures to radiation. *Picker X-Ray Corp.*

1127. Radiation Products
8-page catalog on equipment for nuclear research. Radioactive sources, shielding and exposure equipment, instruments, services. *Budd Co.*

1128. Radiography
16-page booklet on materials and accessories for industrial radiography. Guide to selection of film. Recommended development techniques. *Eastman Kodak, X-Ray Div.*

1129. Rare Earths
New 42-page book on rare earths. Bibliography. Applications in nonferrous metallurgy. *Davison Chemical Co.*

1130. Recorder
New 24-page Bulletin RI-8-57 on recorder and accessories. 8 tables, many diagrams. *Riehle Testing Machines*

1131. Recorders
New 4-page Data Sheet ND46-20 (1) on recorders and indicators for precise measurement of pressure, force, tension and weight. Applications. *Leeds & Northrup*

1132. Refractory Metals
Booklet on tungsten, molybdenum, tantalum, their properties and uses. *Fansteel Metallurgical*

1133. Rust Preventive
New bulletin on wetting agent and emulsifier for use as a rust preventive and corrosion inhibitor. *Swift & Co.*

1134. Rust Remover
New 4-page folder on alkaline rust remover. How and where to use it. *Turco*

1135. Salt Bath Descaling
12-page Bulletin B-40 describes continuous and batch descaling lines for removing oxide from steel, bronze, copper, stainless and titanium. *Drever Co.*

1136. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

1137. Salt Baths
Bulletin 200 tells about different types

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Remember the old tomb-type furnaces with their limited capacities, packed doors, week long processing cycles? Long time ago wasn't it? . . . "King Tut", above, dates back to 1916, in fact. Then, in '22 Holcroft developed a new process for malleable annealing. "Tombs", heavy boxes, packing, long cycles were eliminated. And with Holcroft engineers leading the way, castings came to be treated in continuous, controlled-atmosphere furnaces. As a result production capacities have been vastly increased . . . cycle time has been reduced to hours . . . quality has reached new peaks . . . manpower, space and fuel needs have been cut to a cost-saving minimum.

Point is, if there's a better, faster, less costly way to do a job of heat treating, you'll find it *first* in a Holcroft furnace . . . and that's a time-tested fact!

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from J&L STRIP STEEL DIVISION

restricted and standard specification cold rolled strip steel

Let's examine this "Full Line" product list of cold rolled strip steel. At J&L it includes all carbon grades, coated and uncoated, alloy, stainless and tempered spring steel. It offers all thicknesses from .001" or less to .156" or more, in widths from ¼" to 24"—and tolerances for gauge and width closer than standard when required. There are "Full Line" advantages, too, in a range of controlled tempers and structures possible only with the variety of annealing, heat treating and rolling processes found at J&L.

Your "Full Line" benefits can start by specifying J&L because only J&L makes standard and restricted specification cold rolled strip steel in such a wide range of analyses, grades and sizes to accurately meet the most exacting need.

For Strip Steel, call the Strip Steel Specialist—J&L.

J&L STRIP STEEL DIVISION produces a full line of restricted and standard specification strip steel in these grades and types:

Low Carbon	Electrolytic Zinc, Tin, Copper & Brass Coated
High Carbon	Alloy
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Molten Zinc Coated (Jal Zinc)	Painted

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of baths and operating characteristics of each. Table of bath recommendations for various steels. *A. F. Holden*

1138. Shear
Bulletin on bar and billet shear for rounds, squares, flats, billets and structurals. either hot or cold. *Hill Acme Co.*

1139. Shell Mold Castings
Data sheet on casting of beryllium copper alloys by the shell molding process. *Ampco Metal*

1140. Sonic Thickness Tester
Measurement of wall thickness from one side by sonic method. *Branson*

1141. Spectrograph
New 8-page catalog on Spec-Lab. Performance and applications of three models. *Jarrell-Ash*

1142. Spectrographic Sources
4-page bulletin 35A on spectrographic source unit gives data on three units available. *Baird Atomic*

1143. Springs
New 16-page Catalog No. 9 on micro processed springs of beryllium copper. Design recommendations, specifications. *Instrument Specialties Co., Inc.*

1144. Stainless Castings
28-page booklet of data on stainless castings. Analyses, properties, handling and heat treatment. Typical applications. *Allegheny Ludlum Steel*

1145. Stainless Fasteners
24-page catalog 56-A lists sizes and types. 7000 items included. *Star Stainless Screw*

1146. Stainless Steel
32-page book on corrosion resistance of stainless steels. 18 tables on tests in acid, neutral and alkaline solutions. *International Nickel*

1147. Stainless Steel
32-page catalog gives chemical composition, strength factors, physical properties and applications of 200, 300, 400 series stainless. *Sharon Steel*

1148. Stainless Steel
12-page bulletin on chromium-manganese austenitic steel. Effect of cold working, properties at elevated temperatures, corrosion resistance, magnetic permeability. *U. S. Steel Corp.*

1149. Stampings
New brochure on stamping and forming of precision small parts. Methods used, equipment for manufacturing, inspecting and testing. *Be Cu Mfg. Co.*

1150. Stampings
16-page brochure on story of stamping. Handy tabular data. *Republic Steel*

1151. Stereomicroscopes
38-page catalog D-15 shows value of three-dimensional microscopes for industrial assembly lines and research laboratories. *Bausch & Lomb Optical*

1152. Sub-Zero Treatment
12-page booklet on industrial chilling equipment for shrinking, testing and treating of metals. *Cincinnati Sub-Zero Products*

1153. Sulphur Determination
Literature on 3-min. determinator for use with combustion furnace. *Dietert*

1154. Temperature Measuring
Bulletins on Tempilstiks and Tempilaq describe products and tell how to use them. *Tempil® Corp.*

1155. Testing
Literature on pickle pills for testing strength of pickling solutions. *Ferro Corp.*

1156. Thermocouples
Chart of color codes and calibration for thermocouples and extensions. Resistance tables for pyrometer wires. *Thermo Electric*

1157. Thickness Tester
Data sheets give ranges, principle of operation of nondestructive thickness tester. *Unit Process Assemblies*

1158. Tin
20-page bulletin on importance of tin to the American industry. Applications in aircraft, chemical, container, electrical, electronic equipment and others. *Malayan Tin Bureau*

1159. Titanium
8-page booklet on corrosion resistance of titanium. Table of ratings of titanium compared with stainless and aluminum in various mediums. *Mallory-Sharon Metals*

1160. Titanium
New bulletin on titanium production and use. Mechanical properties. *Republic Steel Corp.*

1161. Titanium Powders
Data on high purity and commercial titanium powders. *Hawkridge Metals*

1162. Tool Steel
Color guide to estimate temperatures has heat colors on one side and temper colors on the other. *Bethlehem Steel*

1163. Tubing
New 6-page folder on tubing applications in nuclear power plants. *Wolverine Tube Div.*

1164. Tungsten
12-page booklet on tungsten coil products for electronic and lighting applications. *Sylvania Electric Products, Inc., Tungsten & Chemical Div.*

1165. Tungsten Alloy
New bulletin on properties and uses of 90% tungsten alloy, balance nickel and copper. *Firth Sterling, Inc.*

1166. Ultrasonic Cleaning
12-page article on new ultrasonic cleaner for use with metallographic specimens. Metal Digest, V. 3, No. 1. *Buehler, Ltd.*

1167. Vacuum Furnace
New Bulletin 807 on laboratory vacuum furnace. Specifications, applications, accessories. *Kinney Mfg.*

1168. Vacuum Furnaces
New 53-page Bulletin No. 4-27 on vacuum arc melting furnaces and pumps. Tables and graphs. *Rochester Div. CEC*

1169. Vacuum Melting
New bulletin on vacuum melting furnaces which can be used in production or for laboratory purposes. *Zak Machine Works*

1170. Welding
Data on welding positioners from 500 to 100,000 lb. capacity. *Harnischfeger*

1171. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

1172. Welding Stainless
New 12-page booklet—a guide to better welding of stainless steels. In question and answer form. *Arcos*

1173. Wire Cloth
94-page catalog on line of industrial wire cloth, screen and wire cloth products. Types, sizes, applications. Metals and alloys used, stainless compositions, corrosion tables. *Cambridge Wire Cloth*

1174. X-Ray Equipment
4-page folder on X-ray viewer. Advantages and applications. *Philco*

1175. Zinc Coating
New 12-page booklet on zinc-coated steel. Fabrication, uses. *Weirton Steel*

1176. Zirconium
8-page brochure on zirconium's corrosion resistant properties. Applications based on this property. *Carborundum Metals Co.*

May, 1958

951	971	991	1011	1031	1051	1071	1091	1111	1131	1151	1171
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970	990	1010	1030	1050	1070	1090	1110	1130	1150	1170	

METAL PROGRESS,

7301 Euclid Avenue, Cleveland 3, Ohio

Please have literature circled at the left sent to me.

Name _____

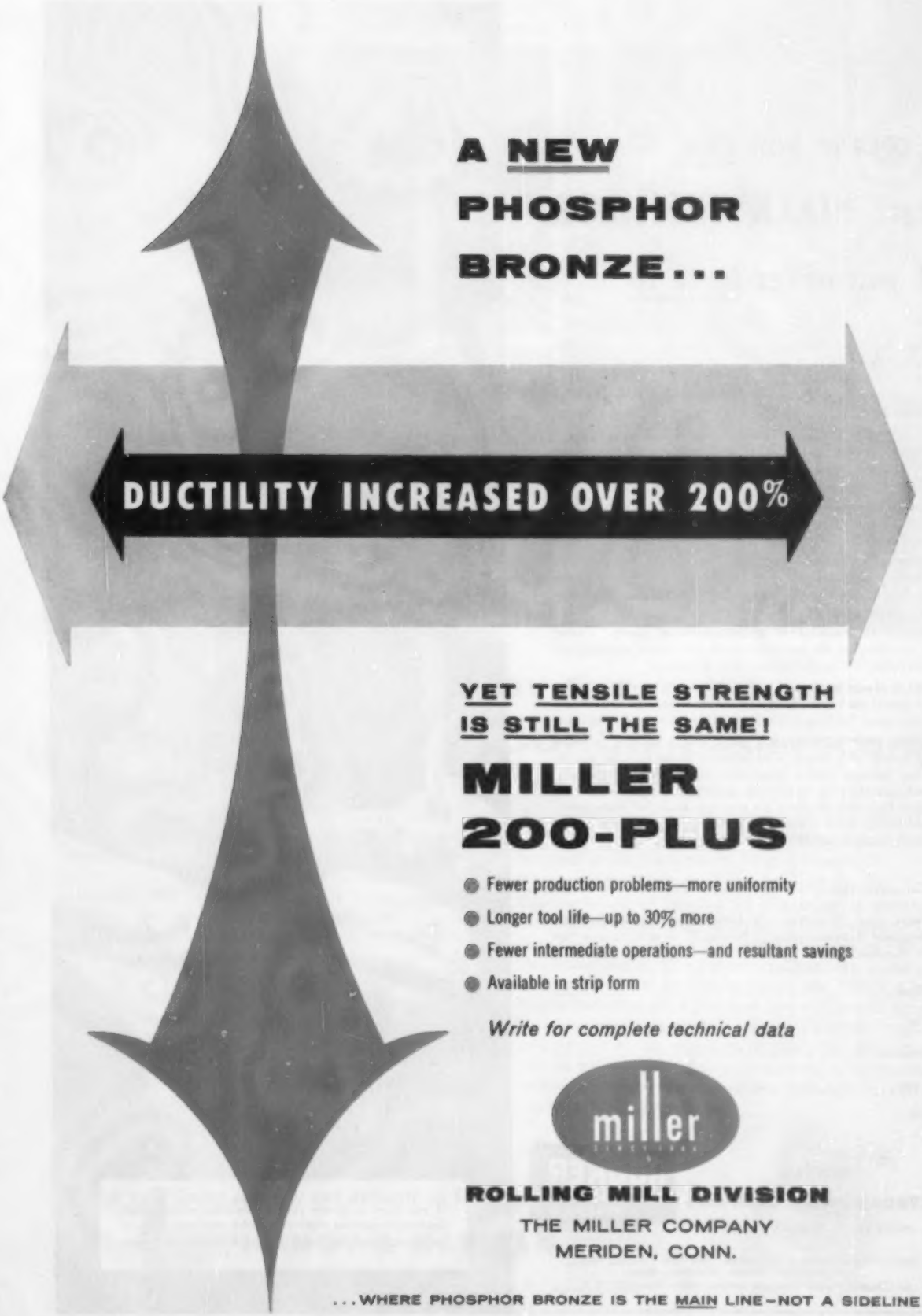
Title _____

Company _____

Address _____

City and State _____

Postcard must be mailed prior to Aug. 1, 1958. Students should write direct to manufacturers.


A NEW
PHOSPHOR
BRONZE...
DUCTILITY INCREASED OVER 200%
YET TENSILE STRENGTH
IS STILL THE SAME!
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Fewer production problems—more uniformity
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...WHERE PHOSPHOR BRONZE IS THE MAIN LINE—NOT A SIDELINE

Of course you can titrate NIALK® TRICHLOR but you never have to

psp is why • The reason you take the time and the trouble to titrate your degreasing solvent is to make sure its stabilizer is still active.

Users of Nialk trichlorethylene find six good reasons why they never *have to* titrate. All six add up to *psp*—permanent staying power.

psp means neutral The neutral Nialk stabilizer cannot react with acids to form corrosive salts. Yet it will "accept" acids and render them neutral and harmless.

psp means insoluble in water You never lose the Nialk stabilizer during steam distillation or in the water separator of your degreaser.

psp means full protection The Nialk stabilizer has the same boiling point as the solvent, so you get complete recovery during distillation and full protection in your degreaser's vapor phase.

psp means no staining or discoloration of parts There are never compounds present which can cause staining or deposit formation on the metals you degrease.

psp means clean bath and coils Nialk trichlor eliminates those deposits on coils which cut down heat transfer. Nialk baths have gone for long periods of time without coil cleaning.

psp works with all metals Even white metals are degreased safely with Nialk. Chlorides of these metals, which might be formed under unusually severe conditions, are rendered harmless by the Nialk stabilizer.

Hooker Bulletin 70 gives a complete study of stabilizers. Bulletin 72 offers a standard titration method for Nialk trichlorethylene. Send the coupon for either.

Please send: ☐ Bulletin 70, Advantages of Nialk Neutrally Stabilized Trichlorethylene ☐ Bulletin 72, Acid Acceptance Test for Trichlorethylene.

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HOOKER
ELECTROCHEMICAL COMPANY
405 UNION STREET, NIAGARA FALLS, N. Y.

HOOKER CHEMICALS PLASTICS

Sales Offices: Chicago Los Angeles New York Niagara Falls Philadelphia Tacoma Worcester, Mass.
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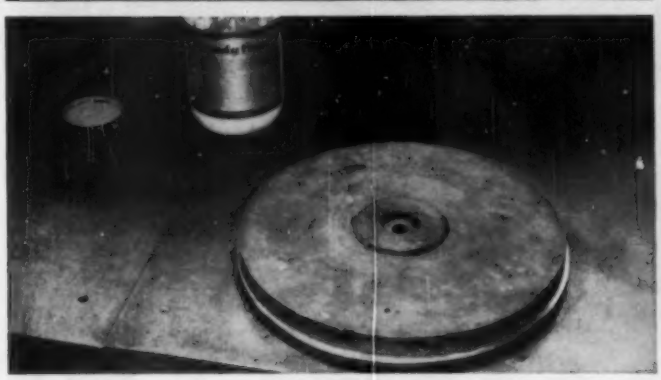
If you have to titrate your degreasing solvent often because it contains stabilizers which wear out, it's time you took a look at Nialk TRICHLORethylene with *psp*.

Insert halves are first carefully cleaned and fluxed. The sheet of EASY-FLO, .005" thick, in three sections, is liberally fluxed with HANDY FLUX. Following this, the halves are put together with EASY-FLO as a "sandwich filler" (below, left). Entire assembly is heated to a brazing temperature of 1170° F.



How EASY FLO Helps COLUMBIA RECORDS make records

EASY-FLO is put to excellent use in the die inserts (or backing plates) used in the manufacture of Columbia Records at the company's Bridgeport, Connecticut, plant. These die inserts are the heating and cooling elements used in the actual plastic record molding; in a very real sense, they are *behind* the entire record-making operation. The die insert assembly consists of two steel plates, the bottom plate being grooved to permit the passage of steam, at a temperature of 300° F under a pressure of 130 lb., followed by cold water at a pressure of 120 lb. When joined, they must be absolutely leak-tight and strong enough to stand up under thousands and thousands of stampings through drastic temperature changes and thermal shock.

These brazed backing plates have a life cycle of some 250,000 records; they are usually retired because of warpage in the steel, rarely for joint leakage.

This example illustrates just a few of the qualities that make silver brazing such a superior joining method. Strength under high pressure, resistance to temperature changes and thermal shock, and production ease; one, or all, of these qualities may apply to your product or production operation. We will be happy indeed to show you how you can benefit from this blue-ribbon method of joining all kinds, shapes and sizes of metals—similar and dissimilar. BULLETIN No. 20 will get you off to a good start on the values, techniques and economies of low-temperature silver brazing. Write for your copy.

Your NO. 1 Source of Supply and Authority on Silver Brazing Alloys

HANDY & HARMAN

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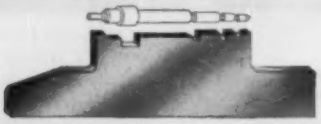
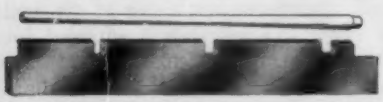
Talide® Blades . . .
THE No. 1 CHOICE OF CENTERLESS GRINDER OPERATORS!

Above view shows Landis Centerless Grinder in operation. Talide-tipped work rest blades have been supplied as initial equipment on many Landis Centerless Grinders.



LARGE ELECTRIC MOTOR PLANT

Part . . . . . Stainless Steel Rotor Shaft for Electric Motor.
Operation . . Grind 7 diameters simultaneously.
Machine . . . No. 12 Landis Centerless Grinder.
Blade . . . . . Special multiple step Talide-tipped work support blade No. C-4884.
Results . . . . Talide-tipped blade in continuous production for 91 days (2 turns per day) compared to best previous production run of 3 days with hard alloy steel blade.



LEADING ARMS PRODUCER reports outstanding service life with Talide centerless blades over past 10 years—outperforming and outlasting all other work support blades.

Part . . . . . 12 gauge shotgun barrel.
Operation . . Grind entire gun barrel simultaneously to series of compound angles.
Machine . . . No. 5 Cincinnati Centerless Grinder.
Blade . . . . . Special Talide-tipped work support blade 34⅜" long, having 9 steps and 10 compound angles ground to .0001" tolerance.
Results . . . . Talide-tipped blades last 150 days per grind—hardened steel blades 3 days. Several Talide blades have been in continuous production for over 5 years—being retipped with a new Talide metal wear strip every 12 to 18 months.

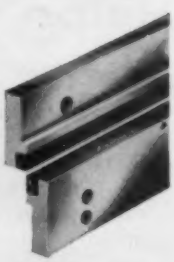
Over 50 sizes and styles of standard blades carried in stock—with special blades made promptly to order. Write for 76-page catalog 56-G or ask for sales engineer to call.

TALIDE ROTARY KNIVES GIVE PHENOMENAL RUN OF 90-1 . . .

A leading strip steel producer of razor blade, high-carbon, spring and stainless steel reports over 1200 coils were gang slitted with Talide knives, compared to 15 coils with steel knives. More tonnage was produced in one regrind of the Talide knives than over the entire life of a set of steel knives. Burr-free, clean-cut edges produced with scrap rate practically eliminated.

$18,000 SAVED USING TALIDE SHEAR BLADES

A large electric motor manufacturer, shearing .014" silicon steel for transformers, advises first-year savings of $18,000 in blade costs after completely equipping their press line with Talide-tipped blades in lengths ranging from 15" to 87". Talide shear blades are averaging 1,000,000 cuts per grind compared to 10,000 cuts obtained with steel blades.



METAL CARBIDES CORPORATION
Youngstown 12, Ohio

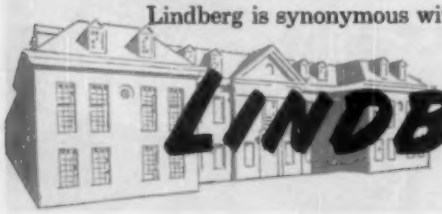
EXCLUSIVE RETIPPING SERVICE

Because of its exclusive hot press method, Metal Carbides is able to rework worn, chipped out or broken areas of carbide-tipped blades back to original size and dimension with all breaks and defects eliminated.

HOT PRESSED AND SINTERED CARBIDES • VACUUM METALS
HEAVY METAL • ALUMINUM OXIDE • HI-TEMP. ALLOYS
OVER 25 YEARS' EXPERIENCE IN TUNGSTEN CARBIDE METALLURGY

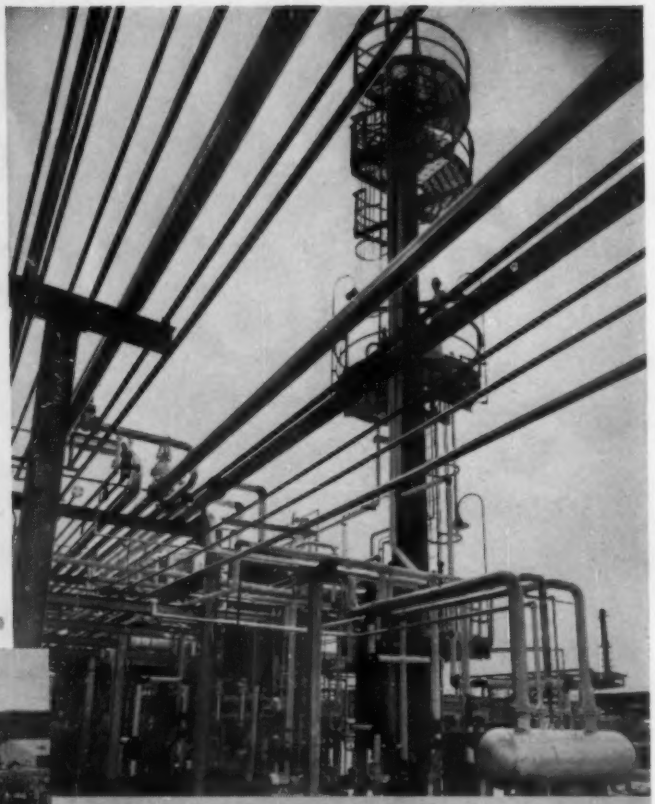
How to find a better heat-treating method

Here's a sound way to do it. Take your problems to the people who have consistently, over the years, provided the metal treating industry with new and better ideas, more efficient, more practical equipment. This will bring you to Lindberg, creators of the famous Cyclone type atmosphere furnaces, the long-life "dimple" vertical radiant tube, the revolutionary new CORRTHERM electric heating element and so many other innovations in better heat treating methods. Lindberg is synonymous with heat treating furnaces. We build them for carbonitriding, carburizing, hardening, tempering, normalizing, bright stainless annealing, brazing, carbon correction, nitriding, or any other metal treating requirement. Give your production processes the advantages of Lindberg's forward look in "heat for industry" techniques. Get in touch with your nearest Lindberg Field Representative (See classified phone book) or write Heat Treating Furnace Division, Lindberg Engineering Company, 2448 W. Hubbard St., Chicago 12, Illinois.



LINDBERG heat for industry

GALVANIZING *Preferred To* PAINTING *For Maximum Low-Cost Protection*



Photos courtesy of Celanese Corp. of America

The Celanese multimillion-dollar Fortiflex plant for production of low-pressure polyethylene used *galvanized* structurals in preference to *painted* steel in all exposed outdoor areas. The plant, situated on a 200-acre site near Houston, is exposed to the highly corrosive atmosphere of that industrial area.

After consideration of the low initial cost of galvanizing, with an expected life of 10 to 15 years, Celanese elected to install galvanized structures. Today after nearly two years of operation, the structures show no sign of corrosion.

Celanese based its use of galvanized steel on experience gained at its petrochemical plant near Bishop, Texas. Experience there has shown paint maintenance to be costly, *requiring new finish coats every 4 years.* On the other hand, galvanized steel catwalks at this plant are still in good condition after 10 years of service. Galvanizing costs as low as $0.17 to $0.33 per sq. ft. for I-beams have been reported. Considering that the zinc in a 2 oz. coating costs only $0.013 per sq. ft., the low cost of galvanizing is understandable. As shown in the comparative cost table below, galvanizing not only has the lowest first cost, but does not have the problem of repainting every 4 years.

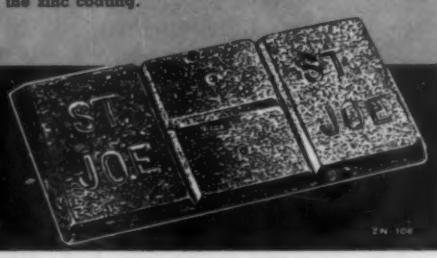
Galvanizing vs. Painting Structural Steel
(Initial cost per square foot)

GALVANIZING[a]		PAINTING[b]			
		Case A		Case B	
		Sandblast	$0.15	Wire brush and chip	$0.05
		Primer	0.05	Primer	0.05
		2 finish coats	0.10	2 finish coats	0.10
Total	$0.20		$0.30		$0.20

[a] Average cost on 200 tons of various-sized pipe supports, based on cost of $50 per ton for 2-ounce coat.
[b] Primer applied as shopcoat; finish coats applied in field.

The Most Effective Method Of Prolonging The Life Of Iron And Steel Products Is To Apply This Long-Established Principle: **The life of a galvanized product is directly proportional to the thickness of the zinc coating.**

ST. JOSEPH LEAD COMPANY
250 PARK AVENUE
NEW YORK 17, N. Y.
The Largest Producers of Lead in the United States



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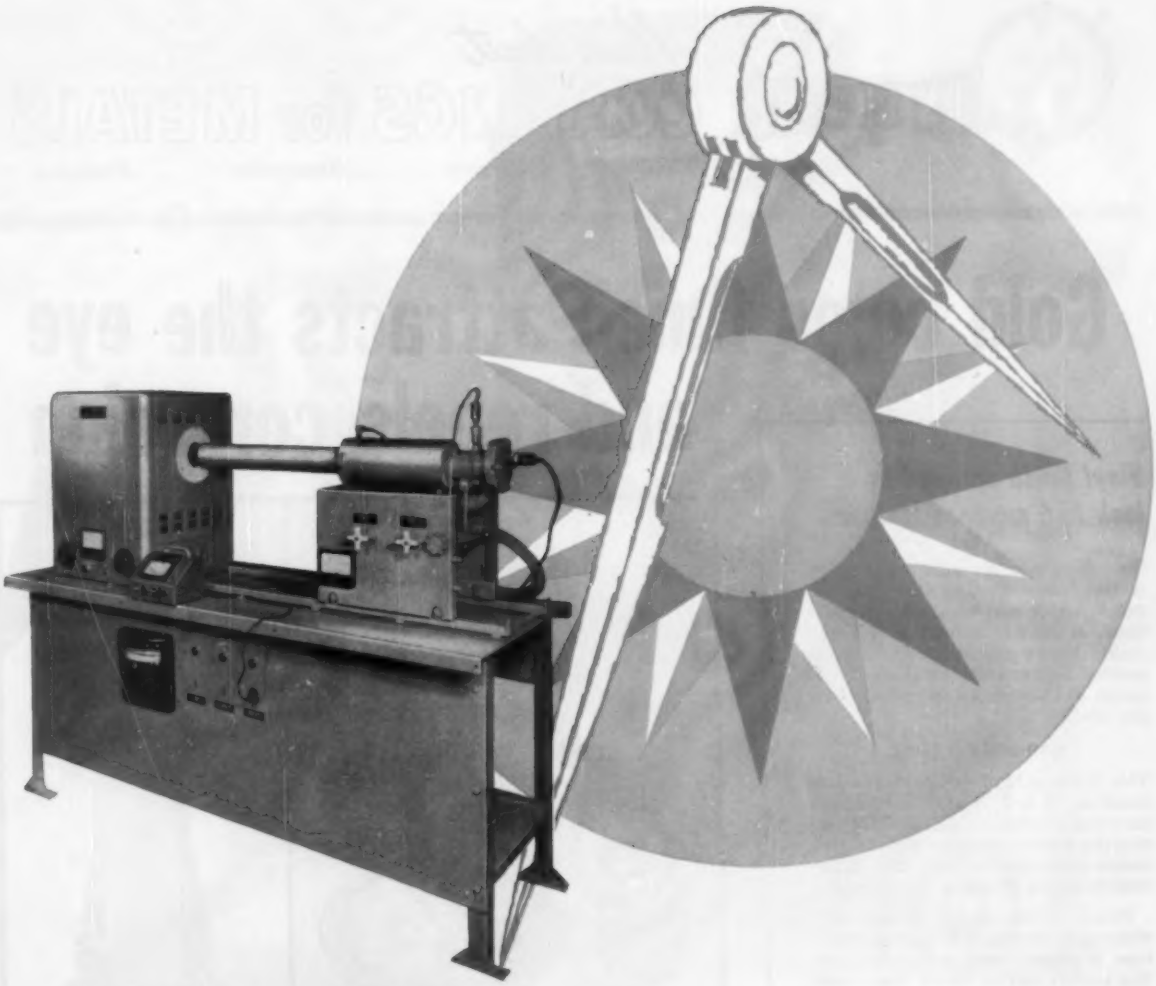


Pilot Plant Equipment... a Lindberg Innovation

When there is something new in "heat for industry" most often it comes from Lindberg. The latest is a new line of Lindberg equipment now available that fills in a long-felt need in metal treating. Our engineers have designed a brand new group of furnaces to bridge the gap between laboratory and production line. This larger-than-lab, smaller-than-standard equipment is designed specifically for pilot plant use. You can test your materials, your methods, on equipment moderately priced but production capable. Fuel-fired, electric and High Frequency units are included. Six different types of furnaces can be supplied including, as illustrated, an electric vacuum-type furnace ideal for testing this newest and most promising heat treating method. Get in touch with your nearest Lindberg Field Representative (See classified phone book) or write Pilot Plant Equipment Division, Lindberg Engineering Company, 2448 W. Hubbard St., Chicago 12, Illinois.

LINDBERG heat for industry

UNICHROME
Trade Mark

News about
COATINGS for METALS
Metallic.....Organic.....Decorative.....Protective

Gold color finish attracts the eye and repels corrosion

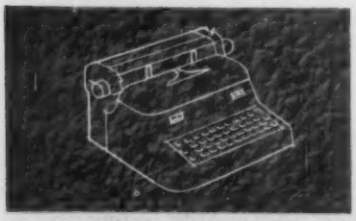
Vinyl finish sprayed to look like morroco leather

Something new for product designers is Unichrome Coating 6400 — a textured, highly mar-resistant protective finish. It can add distinction and durability to any product. It has a costly grained leather look, yet is applied by spray, in thicknesses of up to 20 mils per coat.

WITHSTANDS ABUSE

This finish is hard yet flexible. By as much as 10 to 1, it outlives ordinary textured enamels under abrasive and abusive service conditions. Taber abrasion tests show only 35 mg. loss in 1000 cycles vs. 350 mg. for the enamels.

Being a vinyl finish, Coating 6400 withstands chemicals, corrosives, moisture. It doesn't stain, is easy to clean. The surface can be varied from matte to gloss. It also insulates electrically, and helps to muffle sound. Send for new bulletin.



With this textured decorative and protective coating, products get the quality finish that befits them.

METAL & THERMIT
CORPORATION
General Offices: Rahway, New Jersey
Pittsburgh • Atlanta • Detroit
East Chicago • Los Angeles
In Canada: Metal & Thermit—United Chromium of Canada, Limited, Rexdale, Ont.

Products finished with M&T Bronze rival gold in appearance, in consumer appeal. Applications are wide as a designer's imagination.

M&T Bronze plating process produces uniform copper-tin plate at high speed

All may not be true gold that glitters, but improved M&T Bronze certainly is the image of the 24K kind.

This distinctive bronze is 88% copper, 12% tin — with uniform color and coverage even on complicated shapes. The finish reflects more depth and character than brass plate; demonstrates more durability than copper. It is a one plate finish, more economical than the copper-nickel-gold it has replaced on trophies, for example.

DURABLE FINISH

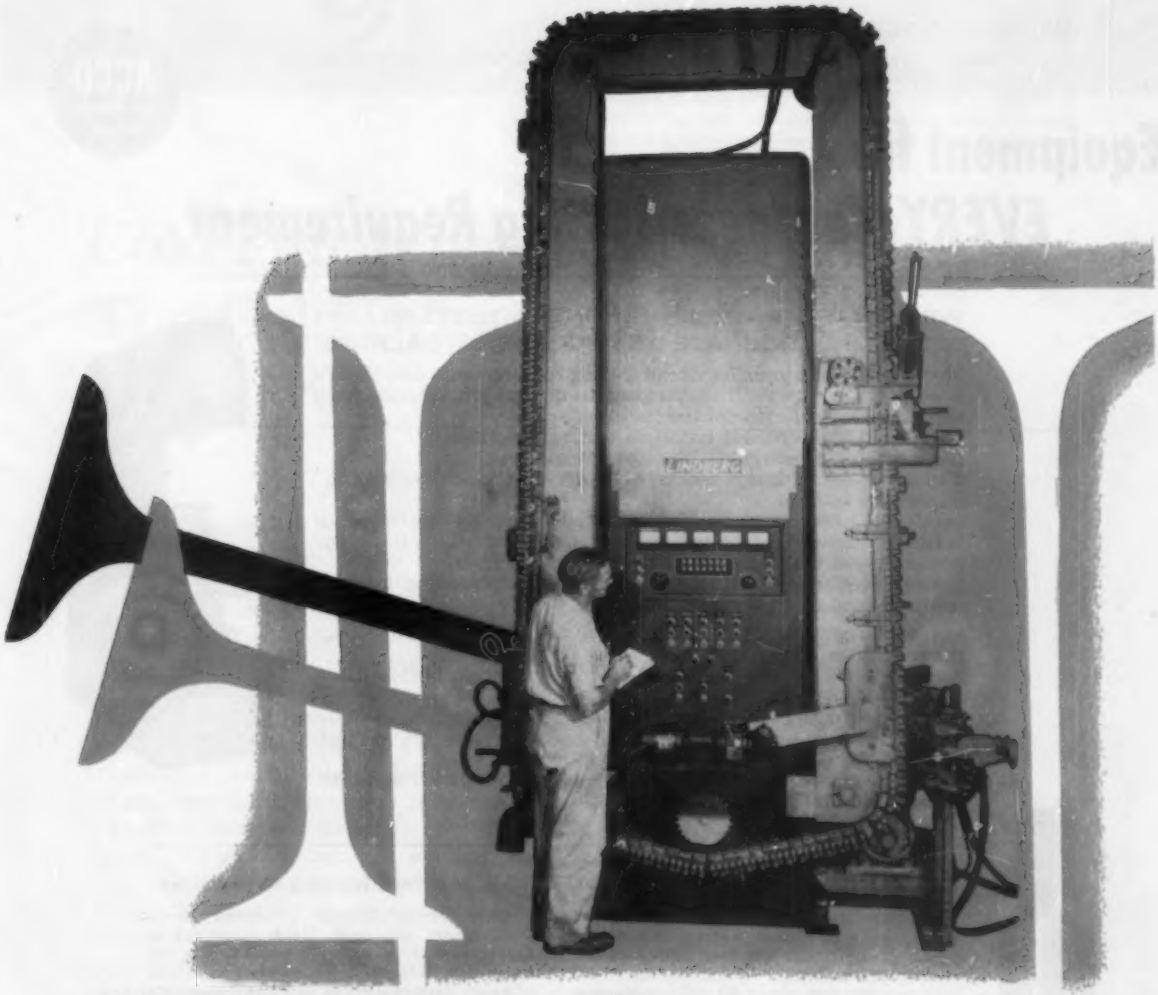
M&T Bronze, in addition to its eye-appeal, offers corrosion resistance superior to that of copper. A clear lacquer or synthetic applied on top of this plate will assure the long, tarnish-free life expected from a quality finish.

ECONOMICAL FINISH

In overall economy, the M&T Bronze process does better than gold or brass plating and rivals copper. It can save production time, being able to plate as fast as one-tenth mil in one minute.

EASY TO USE

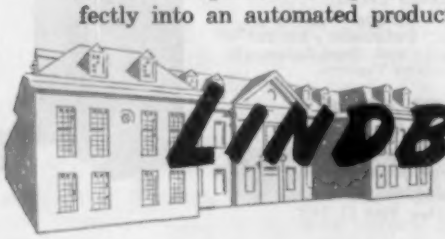
Since the M&T Bronze Process is as easy to control and to operate as those depositing single metals, it assures consistent results. It can be plated matte as well as mirror-bright, or anywhere in-between. Send for data.



Lindberg pioneers in High Frequency Heating

Along with its pioneering in all phases of "heat for industry" Lindberg is one of the largest makers of High Frequency heating units. Our "H-F" designers and engineers have made outstanding developments in this important heat treating field. For example, we illustrate a remarkable unit just recently completed for aluminizing automotive valves. It was designed vertically, saving 60% of floor space, and is completely automatic. No operator is required. It fits perfectly into an automated production line.

Our High Frequency Division provides units for hardening, brazing, heating for forging and forming, annealing and many other processes, and designs a variety of fixtures for application to "H-F" units. Lindberg also supplies a complete line of motor generators for all induction heating and melting applications. Get in touch with your nearest Lindberg Field Representative (See classified phone book) or write High Frequency Division, Lindberg Engineering Company, 2448 W. Hubbard St., Chicago 12, Illinois.



LINDBERG heat for industry

WILSON "ROCKWELL"
HARDNESS TESTERS • *WORLD'S STANDARD OF ACCURACY*

ACCO for Better Values

Equipment for *EVERY Hardness Testing Requirement*

WILSON "ROCKWELL" HARDNESS TESTERS ...ACCURATE AS A PRECISION BALANCE

No matter what your hardness testing requirements are, there's a WILSON "ROCKWELL" instrument to do the job. Choose from this complete selection of hardness testers:
"ROCKWELL"—for most hardness testing functions.
Superficial—for extremely shallow indentations.
Twintester—combines functions of "ROCKWELL" and "ROCKWELL" Superficial testers.
Semi-Automatic (manual feed) and Fully Automatic—for automatically classifying tested pieces as CORRECT, TOO HARD, or TOO SOFT—at test rates up to 1000 pieces per hour.
Special Machines—for testing large objects, obtaining internal readings, and other unusual applications.

ALL WILSON "ROCKWELL" hardness testers provide these advantages:
Accurate performance—precision built, with exact calibration, for consistently correct results.
Long life—durable as a machine tool.
Easy operation—even an unskilled operator can get perfect readings. All controls conveniently grouped.
Easy maintenance—interchangeable mechanisms, with spindles mounted on oil-less bearings.

DIAMOND "BRALE" PENETRATORS ... perfect testing every time

A perfect diamond penetrator is essential to accurate hardness testing. Since one point of hardness on the "ROCKWELL" scale represents only 80 millionths of an inch penetration—only 40 millionths on a Superficial tester—the slightest imperfection will cause a false reading.

Only *perfect* Wilson Diamond Brale Penetrators are sold. Each diamond is flawless, with no chips or cracks. It's cut to an exact shape. Microscopic inspection of every diamond—one at a time—assures this perfection—and assures you of accurate hardness testing every time.

TUKON TESTER ... for precision MICRO & MACRO testing

The TUKON Tester measures extremely shallow indentations. It's used, for instance, by manufacturers of watches, hairsprings, needles, and fine wire. Laboratories use the TUKON for tests on individual crystals or particles of microscopic size. Producers of coatings, film, ceramics, and many other materials have made good use of the TUKON.

Three models are available to meet your individual requirements. TUKON Testers use both the Knoop and 136° Diamond Pyramid Indenter. Each TUKON Tester is a self-contained hardness testing instrument— no accessory equipment is needed. Knoop edges and levers of fixed length are used throughout for application of exact load and freedom from internal friction.

A COMPLETE LIBRARY of helpful information

A wide variety of bulletins describes the many instruments, accessories, and services Wilson offers. Write for your choice:
DH-325—WILSON "ROCKWELL" Hardness Testers • **DH-326**—"ROCKWELL" Superficial Hardness Testers • **TT-58**—"ROCKWELL" Twintester • **DH-327**—Special "ROCKWELL" Testers, including Automatic and Semi-Automatic models • **DH-7**—TUKON Applications • **DH-328**—TUKON Testers.

ACCO **WILSON**
MECHANICAL INSTRUMENT DIVISION
AMERICAN CHAIN & CABLE
230-F Park Avenue, New York 17, N.Y.

XXVI

This is the twenty-sixth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Cold-Finishing of Alloy Steels: The Cold-Drawing of Bars

Cold-finishing of alloy bars may be divided into two general categories: (1) cold-drawing, where the bars are pulled through a die with no surface removal; and (2) turning and grinding, which removes the surface. We shall consider the cold-drawing procedure in this discussion.

Cold-drawing is the process of pulling a pickled and limed bar through a die, which results in a bright, smooth finish of the section, combined with close tolerances. The alloy bars are prepared for cold-drawing by pickling in a hot solution of dilute sulphuric acid for removal of scale. This is followed by a water rinse, and immersion in a hot lime-water bath to neutralize the effects of the acid, and to aid in carrying special liquid lubricants into the die.

Alloy bars may be cold-drawn under four conditions: *as-rolled*, *normalized* (low-carbon grades only), *annealed* (lamellar or spheroidized), or *quenched and tempered*. These conditions are determined by the grade of alloy steel, the resultant hardness, and the mechanical properties desired for a given end use.

In cold-drawing, the alloy bar is machine-pointed, to reduce the size at one end so it will pass easily into the die opening. Otherwise, the bar is pushed or extruded into the die by an auxiliary device. A die-holder, which can be made to contain from one to four dies, is mounted in an appropriate head assembled across a "draw bench," so that from one to four bars can be drawn at the same time. The draw bench has a bed which accommodates a 4-wheel buggy with jaws that grip the pointed ends of the bars as they emerge from the dies. The buggy has a hook on one end which engages an endless chain, thus pulling the bars through the dies for their entire length.

After cold-drawing, each bar feeds automatically into a straightening machine, and is sheared or "cracker-cut" to length on appropriate machines. Saws are used when the cross-sections of the bars are too large to be cracked or sheared, or when clean square ends are required.

Smaller sizes in the form of coils are drawn on "bull-blocks," or "wire-blocks," depending on sizes, followed by straightening and cutting on special machines.

Specifications with respect to chemical composition, grain size, hardenability, and the like, of cold-drawn alloy steels have been given long study by Bethlehem metallurgists. If you would like suggestions on cold-drawn products, or any other problem concerning alloy steels, our metallurgists will be glad to give you all possible help, without cost or obligation on your part.

In addition to manufacturing the entire range of AISI alloy steels, Bethlehem produces special analysis steels and the full range of carbon grades.

If you would like reprints of this series of advertisements, please write to us, addressing your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. The subjects in the series are now available in a handy 40-page booklet, and we shall be glad to send you a free copy.

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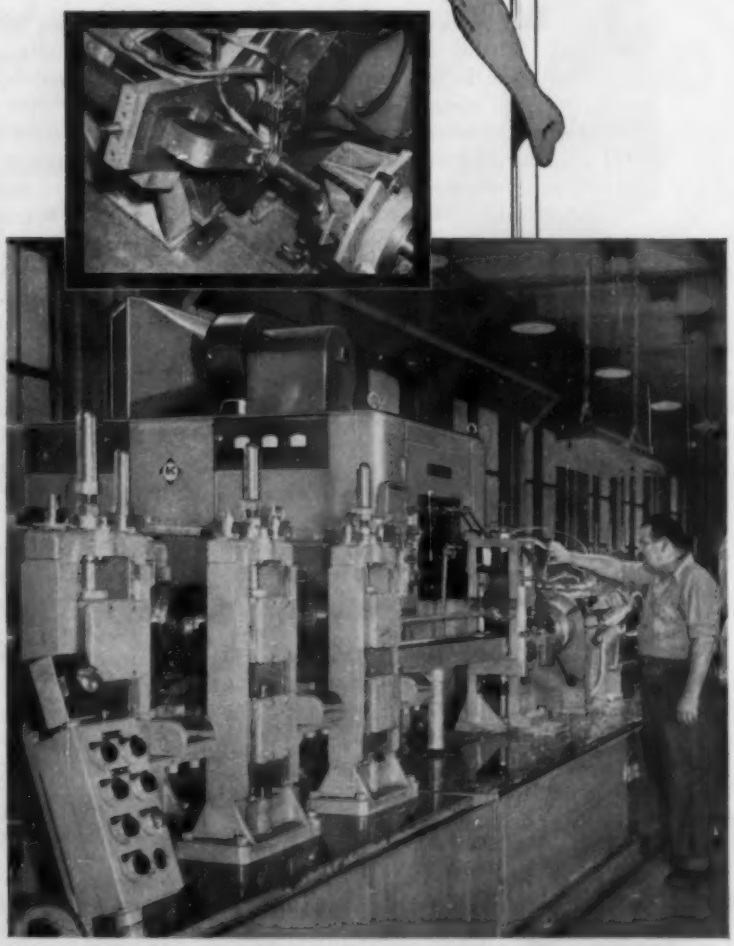

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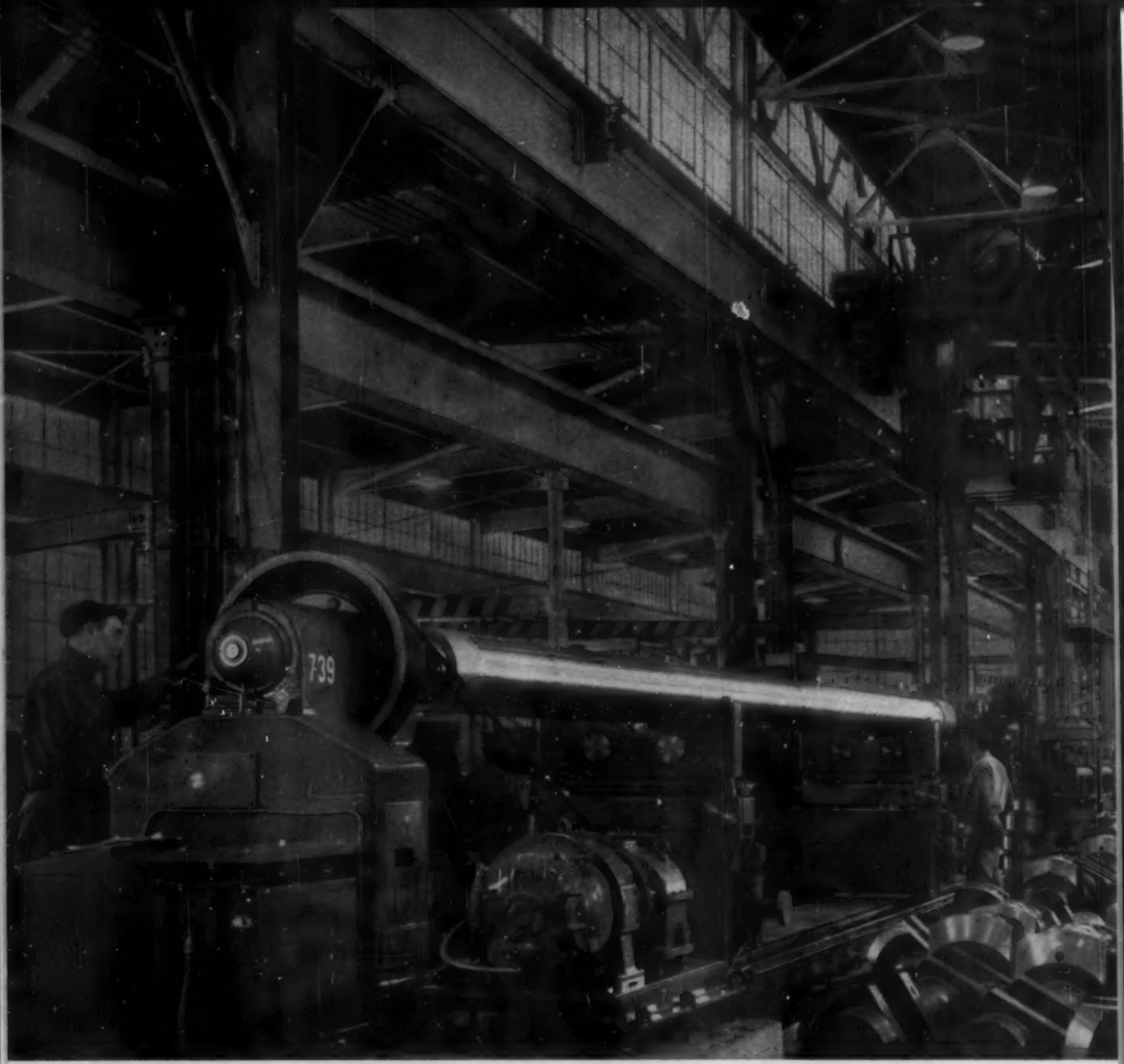

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MOLY NEWS

CLIMAX MOLYBDENUM, 500 FIFTH AVENUE, NEW YORK 36, N.Y.

Chrome-Moly Steels Prove Ability To Resist Wear and Abrasion, Cut Costs

Can be Adapted to a Wide Range of Uses

To offset rising equipment and maintenance costs, the savings possible with wear-resistant alloy steels are receiving increasingly wide attention, in a growing number of industries.

Two types of "Chrome-Moly" steels show exceptional resistance to abrasion and wear under toughest conditions. Both have substantially cut liner costs and shutdown time in grinding mills. Both are suitable for a variety of other industrial applications because they combine wear resistance, favorable first cost, freedom from premature failure by breakage or spalling, resistance to flow in service, consistently uniform performance and adaptability to specific designs.

The two types are Pearlitic (250-450 BHN) and Martensitic (450-700 BHN). Carbon and alloy contents and heat treatments of both types can be varied to suit specific applications.

Note that the spiral wear pattern is clockwise, even though the mill's rotation is counter-clockwise. Type 2 Martensitic steel is used here.

For an article on the use of Chrome-Moly steels, send for "How to Select Chrome-Moly Steels for Ball and Rod Mill Liners" by T. E. Norman, reprinted from Engineering and Mining Journal. Circle #1 on the coupon.

New Use For Super-Strength Structural Steels

Today, gasoline trailer tanks are built of super-strength structural steels for a good reason. The steels have high strength/weight ratios. This factor enables builders to design tanks that carry greater payloads and still meet legal gross weight limits. And the extra capacity pays for the higher trailer cost in a few months!

This use is only one of countless possibilities for utilizing the steels' minimum yield strengths of 55,000 to 150,000 psi . . . and their many other desirable properties. *For more information, including tradenames and compositions, ask for "Super-Strength Structural Steels." Circle #2.*

Sums Up Moly's Resistance to Corrosion

A new paper, "Corrosion Resistance of Molybdenum and Molybdenum-Base Alloys," based on published literature, summarizes moly's resistance to a number of corrosive media. It also lists the reference articles. For a copy of this paper, *circle #6.*

Molybdenum Improves Corrosion Resistance of Stainless Steels

Translated excerpts from two French articles discussing how moly improves the corrosion resistance of austenitic and austenitic-ferritic stainless steels are now available. *Circle #7.*

Special Steels Solve Hydrogen Sulphide Problem

Hydrogen sulphide in France's Lacq natural gas field brought up a metallurgical problem: the need for tubing meeting the N-80 strength requirements but with better resistance to sulphide stress corrosion than the conventional N-80 grade. Two such steels have been developed. One contains chromium, aluminum and molybdenum; the other contains chromium, molybdenum and vanadium.

For articles discussing both steels, send for "A Special N-80 Steel Tubing . . . " by Cauchois, Didier and Herzog, reprinted from *Corrosion*, and "Comments on new French N-80 Steels" published by Climax. *Circle #3.*

Vanadium in Low-Alloy, High-Temperature Steels

Molybdenum is a must in low-alloy, high-temperature steels. However, recent tests at the U.S. Naval Research Laboratory point up the role of Vanadium in such steels, and show the effect of variations in composition and treatment. Addition of Vanadium results in a better high-temperature alloy, but getting the improvement requires higher normalizing temperatures.

The advantages and limitations are described in an *Iron Age article*, "Higher Vanadium Improves Hot Strength of Low Alloy Steel," by Paul Shahinian and J. R. Lane. *For reprints, circle #4.*

New Cleaner Removes Surface Oxides From Moly Metal

A practical, low-temperature method of cleaning molybdenum has recently been developed. It is especially suitable for removing surface oxides prior to welding. The process involves two chemical baths: one at 150-180°F, the other at room temperature. *Digested from "Ryan Devises Molybdenum Cleaner," Ryan Aeronautical Company. For reprints, circle #5.*

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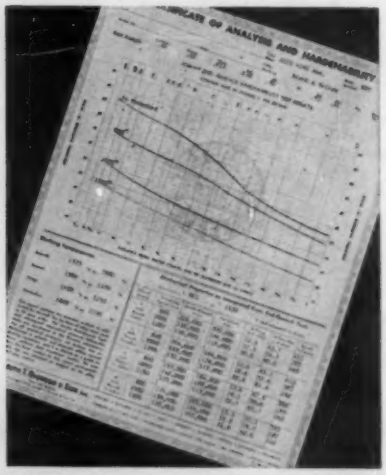

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Metal Progress
Volume 73, No. 5 May 1958

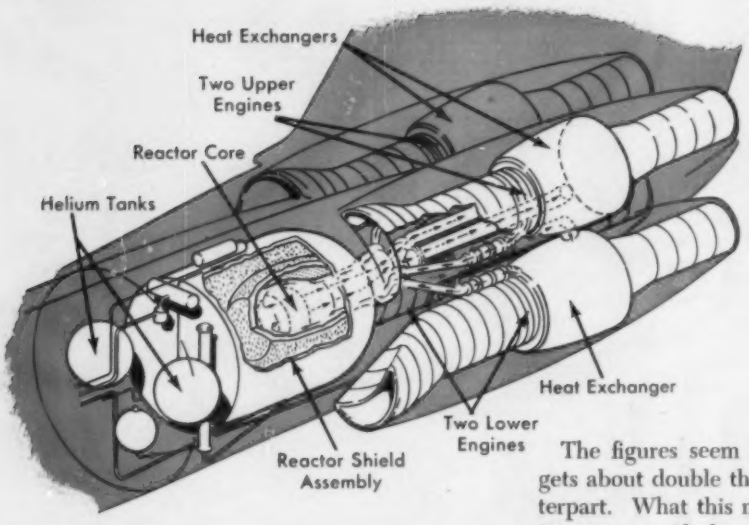
Heating With an Electron Beam

THE ATOMIC ENERGY COMMISSION has a Connecticut Aircraft Nuclear Engine Laboratory (dubbed CANEL) at Middletown some 15 miles south of Hartford and operated by Pratt & Whitney Aircraft as contractor. My visit coincided with a conference for faculty members of engineering colleges in New England and Eastern New York, wherein CANEL'S work in chemistry, instrumentation, corrosion, high-temperature materials and metals was considered. The object was to show the excellent equipment available and the challenging problems to be solved, hoping thereby to enlist the teachers' help in recruiting young graduates.

There are two main concepts of nuclear aircraft power plants. In simplest terms, one heats air by passing it through the atomic reactor and this hot air is the propellant, either giving direct thrust as in a jet or acting as a hot fluid to power a turbine. This "direct" approach is the main problem of the laboratory at Evandale, near Cincinnati, operated by General Electric Co. The other concept is to use some intermediate (liquid or gas) to transfer heat from the reactor core to an interchanger or some other power-producing mechanism. This is the problem of the Connecticut Engine Laboratory; the installation is fairly new and the staff since 1951 has been studying numerous and intricate problems on the new technological frontier, and has manufactured and tested some small components.

In this, of course, they are working with very difficult materials. It seems a peculiar fact that the metals which have the best performance in reactors – strong at high temperatures, resistant to chemical action or alloying with the environment, inert to intense radiation – are also the most susceptible during reduction and fabrication to contamination by such common neighbors as refractories, oil, air. Ordinarily they are made by reducing a highly purified chemical compound to metal powder or sponge, compacting this into bars to be used as consumable electrodes to make small arc-melted ingots under a fairly good vacuum – even double-melting for better distribution of alloying elements. One difficulty is that the arc becomes quite unstable as the vacuum gets really high. Another is that *some* contamination from the electrode is inescapable.

The metallurgists at CANEL are therefore giving some attention to melting by a focused stream of electrons emitted by an incandescent tungsten coil – a scheme suggested by Temescal



Arrangement of a Four-Engine Propulsion Plant Proposed by DeHavilland of England. The heat transfer medium is helium gas at 1000 psi. Heat exchangers deliver air at 1000° C. to turbines and exhaust thrust. Courtesy Nuclear Power

Metallurgical Corp. of Richmond, Calif. A really high vacuum, of the order of 0.1 micron, is necessary for the operation of such an "electron gun", and this not only prevents contamination of the melt but also sucks out any gas or volatile impurity which may exist in the raw material. It also enables the metallurgist to hold the metal in a molten state as long as is desirable. The melt stock is bombarded with electrons, and molten metal drips into a water-cooled copper crucible below. A second gun may play on the melt to maintain a pool, and the crucible can be merely a ring with a retractable bottom so bars of considerable length may be cast semi-continuously.

E. E. T.

Englishmen Underpaid?

The Institution of Metallurgists of Great Britain has reported the results of its second "Salary Survey" in September 1956. The members are divided into three categories, Licentiates, Associates and Fellows. The Institution has 827 members in the last-named category, and 50% of them returned the questionnaire. It is interesting to compare the median salaries for this senior group with the average salary at the same age of metallurgists in the American Society for Metals, as reported by Walter Morrison in February *Metal Progress:*

Age	Median Salary in Great Britain	Average Salary in America
40	£2000 or $5600	$11,500
50	£2250 or $6300	$14,000
60	£2375 or $7000	$15,000

The figures seem to show that the American gets about double the salary of his British counterpart. What this means in take-home pay less income tax and plus social services, is conjectural. Again, the real purchasing power of the money in the two countries may favor the frugal Englishman. Likewise he and his wife get along without as many gaudy motorcars or electric dishwashers, but it is the Editor's observation that his gracious friends in England are leading full lives and are not too discontented.

E. E. T.

Theory Versus Practice

A salty comment from that modern salt, Admiral H. G. Rickover, daddy of the Navy's atomic submarine, may be quoted from his recent paper before the Society of Naval Architects and Marine Engineers:

"To outward appearances, pressurized water reactor plants now under construction for naval use compare unfavorably with many of the nuclear propulsion plant proposals that are continually being generated. Each new concept generally describes a plant with the following characteristics: (*a*) It is simple; (*b*) it is small; (*c*) it is cheap; (*d*) it is light; (*e*) it can be built very quickly; (*f*) very little development is required – it will use mostly 'off-the-shelf' components; and (*g*) the reactor plant is in the study phase – it is not being built now.

"On the other hand, a real reactor plant can be distinguished by the following characteristics: (*a*) It is being built now; (*b*) it is behind schedule; (*c*) it is requiring an immense amount of development on apparently trivial items; (*d*) it takes a long time to build because of the engineering problems; (*e*) it is large; (*f*) it is complicated; and (*g*) it is heavy."

Standing on the Site of the New Administration Building, Looking West Toward Cleveland, Is "Metals Park", the Home of A.S.M. of Tomorrow

A.S.M.'s New Headquarters

*By WILLIAM H. EISENMAN**

AN IMPORTANT MILESTONE was passed in the history of the American Society for Metals when, early in April 1958, the blade of a bulldozer was driven into the lush landscape at Metals Park to start the excavation for the new home of the Society. Access roads from Ohio State Highway 87, a quarter-mile to the north, had already been built, and we are assured that the 90 people on the Cleveland staff, now scattered in five different locations, will all be housed in the new headquarters building before the end of 1959.

It may be revealing to recount the events since the fall of 1953 when the Board of Trustees made the first appropriation for the building.

Urban or Suburban – At the outset it was necessary to decide whether the new site should be urban, a problem studied by a "Policy and Site Committee" whose five members were ⊖ trustees or past presidents. Advice from real estate men, architects, and city planners was secured about the possibility of expanding our present real estate holdings at 73rd and Euclid in mid-town Cleveland, of modernizing one of the available office buildings in downtown Cleveland, of buying some space at University Circle, Cleveland's educational and artistic center, or of selecting some suburban site. Decision by the Board of Trustees to go suburban was unanimous when it became apparent that a sufficient area of land to house the "A.S.M. of Tomorrow" in built-up areas would be impossibly expensive.

Suburban, but where?

A group of staff members was formed to study the possibilities. They worked closely with an advisory board consisting of Architect Benj. S. Hubbell, Jr.; Howard Whipple Green, chairman of Cleveland's Real Property Survey and expert in population trends; Landscape Architect Wm. A. Strong; Proctor Noyes, chief of Cleveland's Regional Planning Commission; and Donald Dunlap of the real estate firm which negotiated right-of-way for the Ohio Turnpike. Nearly two dozen available sites were sufficiently examined to narrow the possibilities to eight. For each of these a preliminary layout showing anticipated buildings, roadways and services was made, and each site appraised as realistically as possible as to accessibility, transportation, present community surroundings and anticipated future changes, taxation, zoning and other features.

Of course no one site was outstandingly good in *all* respects. The Board of Trustees held two special meetings to inspect each area carefully

*Secretary, American Society for Metals.

Architect Kelly Shows Secretary Eisenman a Wash Drawing of the New Administration Building With Its Circular Piazza on Which Is Erected a Domed Space Lattice. The semicircular building embraces a sunken garden

and evaluate the staff's appraisals. In the end, the Board was pleased to accept my gift of 100 upland acres of "Sunnimoor", a tract of beautiful rolling country, part wooded, part farmland, 10 miles east of Shaker Heights' transit terminal.

Architecture – Next came the problem of architecture, of getting a building which would embody the wonderful world of metals, would express the soaring opportunities of metals engineers, would harmonize with the beautiful landscape, and would serve functionally the headquarters staff – all this within our comparatively modest budget accumulated by yearly appropriations from earned surplus. About a year was spent in negotiations with architectural firms of national fame without securing a preliminary design which, in the opinion of the Board of Trustees, met the above requirements. Fortunately a young Cleveland architect, John Terrence Kelly, then appeared on the scene with fresh ideas, quite inadequately pictured in the engravings. Let me quote his own words:

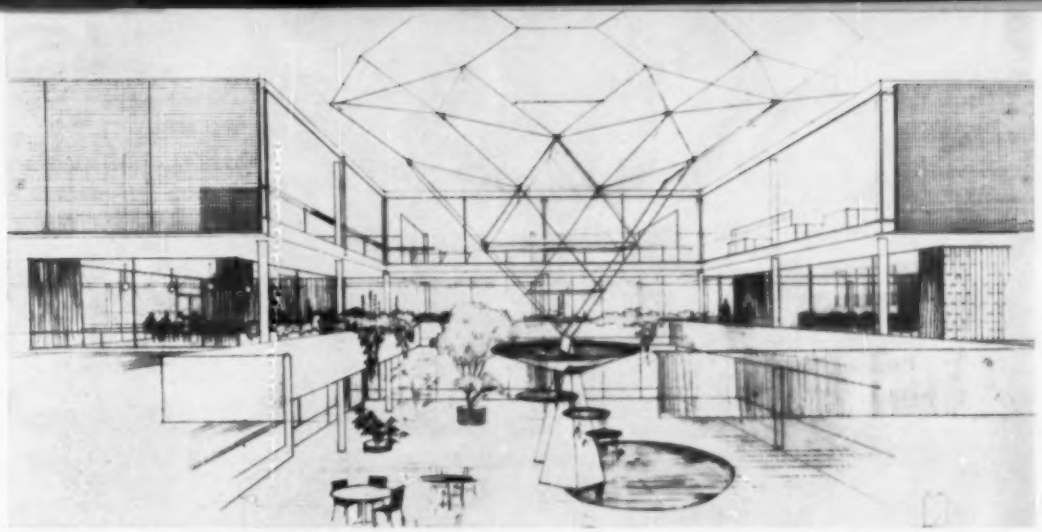
"The completely beautiful site and its tranquility demanded architecture that would complement these qualities. Consequently, the design for the A.S.M.'s headquarters building is a Garden Environment placed into the rolling landscape which we hope will quietly become a part of the Ohio countryside.

"This Garden Environment is made up of four elements: (*a*) a Garden Piazza, 400 ft. in diameter, within which is erected (*b*) a Space Lattice, 250 ft. in diameter and 103 ft. in height, (*c*) the Building proper, which acts as a vertical screen for the composition, and (*d*) a sunken Mineral Garden 100 ft. in diameter in the center of the Garden Piazza.

"The Garden Piazza is located on a rise in the rolling open land so that the lawn grass and planting close to the building will contrast with the long grass of the surrounding meadows. The desire to define the Garden Environment vertically, and still permit one to see the trees and sky, led to the use of a Space Lattice – a dome, or rather double dome, open to the sky. It will be constructed of 4-in. aluminum tubing in a hexagonal pattern. Its lower chord will be at a level to clear the building roof and the entire dome will be supported by five triangular latticed pylons, 22 ft. high, rising from the Garden Piazza. (Two of them come down into courts of the building itself.)

"The Building is semicircular in plan, aligned with the Dome above. It consists of three levels and contains about 50,000 sq.ft. of office space. Its middle level is largely open court leading from outer promenade to Mineral Garden. The building will have a 'sun shield' of perforated copper sheet along its 400-ft. west face. This waistband of copper will contrast and highlight the beauty of the dome's aluminum space lattice. While the general construction will be of concrete slab and glass curtain walls, they will be mounted on exposed steel columns, thus further emphasizing metals in modern construction.

"With the Mineral Garden we hope to express the raw minerals and ores found in nature, and with the dome or 'space lattice' to show what Man with Technology has accomplished with metals from these minerals."



Architect's Sketch of Court in Lower Level With Stainless Steel Pyramids Supporting Aluminum Space Lattice. On the level at this region is the dining room; on middle level at left is a conference room, at right is the board room; on top level are offices for staff members. A copper lattice shields the glass walls from the western sun

To me this new administration building is the culmination of 40 years of service to the American Society for Metals. Yet it is truly only the first stage of the A.S.M. of Tomorrow. As outlined in my address to the Annual Meeting of the Society in 1954, this involves five great steps to progress. The first three already have been approved and are now in motion: Erection of an adequate new Headquarters Building, creation of the Metals Engineering Institute, and creation of the ⊜ Metallurgical Seminars. For the future are the ⊜ Metal Research Institute, and the ⊜ Metal Science University.

In a way the dome, which to a metal scientist, suggests a space lattice, may represent the whole A.S.M. of Tomorrow, and the five pylons the five divisions on which the future structure will rest. I also like to think of the dome as representing the metallurgical world in all its ramifications and the five supports as symbolizing

Education
Research
Engineering
Production
Management

Not only do these five bases support the whole metals industry but the lacy structure shows how intimately all these are connected, how you can start at any point and get to any other by direct or by a devious route, how all are tied to each other.

The Headquarters Building – This account can end with a brief description of the building itself. One illustration shows the lower terrace at the pylon "well" and its clean pier of stainless steel which carries also a series of metal basins with water cascading to the pool in the court. The eye looks toward the central garden, and indicates well the airy appearance of the middle level of the headquarters building.

This middle level also contains the entrance lobby and lounge, lying between the two courts enclosing the dome supports. Adjacent to the lobby will be coat rooms, a conference room, and an assembly room for 125 people. This latter is to be available for community and technical groups. In like manner, the library will be open to the public.

Executive offices and a 22 × 30-ft. board room are to be located in the southern end of the semicircle, and look out on the garden piazza in one direction and on the rolling landscape of Metals Park in the other direction.

Plans call also for a small nonsectarian chapel some 18 ft. square just off the lobby. It will be a spot for contemplation and prayer. In contrast to the open characteristics of other rooms, the chapel will be fully enclosed; light enters only from above, thus creating a dimensional relationship with infinity.

Another unusual room, 20 × 40 ft. in size, on the lower level will be the Albert Sauveur Memorial Room, containing exhibits of historic, educational and scientific interest to the metals industry and to the public.

The top level will be given over completely to a series of offices, based on module spacing, for people of the Society's main operating departments. Here also will be temporarily housed the rapidly growing Metals Engineering Institute, pending erection of a building of its own, probably the second structure to be erected in Metals Park, the A.S.M. of Tomorrow. ⊜

Atomized Powder Alloys of Aluminum

*By R. J. TOWNER**

When molten aluminum alloys – for example 8% iron – are atomized, the fine powder can be compacted and extruded into metal parts with superior strength and structure stability at 400 to 800° F.
(H10f, Q-general, 2-62; Al)

POWDER METALLURGY of aluminum has received considerable attention since 1948, when sintered aluminum powder (SAP) was announced by its originator, Aluminium Industrie Aktiengesellschaft (AIAG). One of the earliest publications in America was by John P. Lyle, Jr., of Aluminum Research Laboratories, in *Metal Progress* for December 1952; he described work on aluminum powder metallurgical products (since designated "APM").

Both SAP and APM are made from aluminum flake powders containing 5 to 17% of Al_2O_3 but no other alloying elements except those occurring as impurities. Their unique high-temperature strength depends on the extremely fine dispersion of insoluble oxide particles throughout the aluminum matrix. The work now to be described concerns parts fabricated during the past several years from atomized aluminum alloy powders, sometimes called pre-alloyed powders. They therefore differ essentially from SAP and APM since they contain intentionally added alloying elements but only incidental amounts – around 0.5% – of oxide. The powder is made by "atomizing" or spraying liquid alloy into the atmosphere; the resulting powder is then compacted and the compacts extruded into the desired shapes. The compositions noted here are the subject of pending patent applications.

Strengthening Mechanisms – The common methods of strengthening aluminum alloys are (*a*) cold working, (*b*) formation of a solid solution, and (*c*) dispersion hardening by a constituent that may be either soluble (as in age hardenable alloys) or relatively insoluble at elevated temperatures. Let us consider these briefly.

1. High-temperature strength can seldom be increased effectively by cold working, because recovery and recrystallization occur when the alloys are heated even to moderate temperatures. Recrystallization, especially, can cause a marked decrease in strength and should be avoided.

2. Solid solution strengthening alone is not very effective at elevated temperatures because the maximum strength that can be attained by this means is relatively low.

3. As far as dispersion hardening is concerned, serious loss in strength occurs at high temperatures when the dispersed phase is soluble in the matrix.

Thus, for elevated-temperature service, producing a dispersion of an insoluble constituent in the alloy is the most useful method for attaining high strength and good structural stability. The SAP and APM alloys are a good example of this, for the solubility of the oxide particles in aluminum is negligible.

A fine dispersion of relatively insoluble constituent in the aluminum matrix may also be obtained in products fabricated from atomized alloy powders. First and most important is the high rate of solidification during atomizing; this

*Physical Metallurgy Div., Alcoa Research Laboratories, New Kensington, Pa. The author wishes to express his appreciation to Messrs. F. H. Stephens, W. D. Helmick, Jr. and A. D. Booz of the Albron Technical Dept., New Kensington Works, for producing the powders. People in several divisions of the Alcoa Research Laboratories were involved in the fabricating and testing of alloys. It is a pleasure to acknowledge helpful discussions with Messrs. E. H. Dix, W. T. Ennor, W. L. Fink, G. F. Sager and J. P. Lyle, Jr. In fact, many of the compositions were selected after consultation with Mr. Lyle.

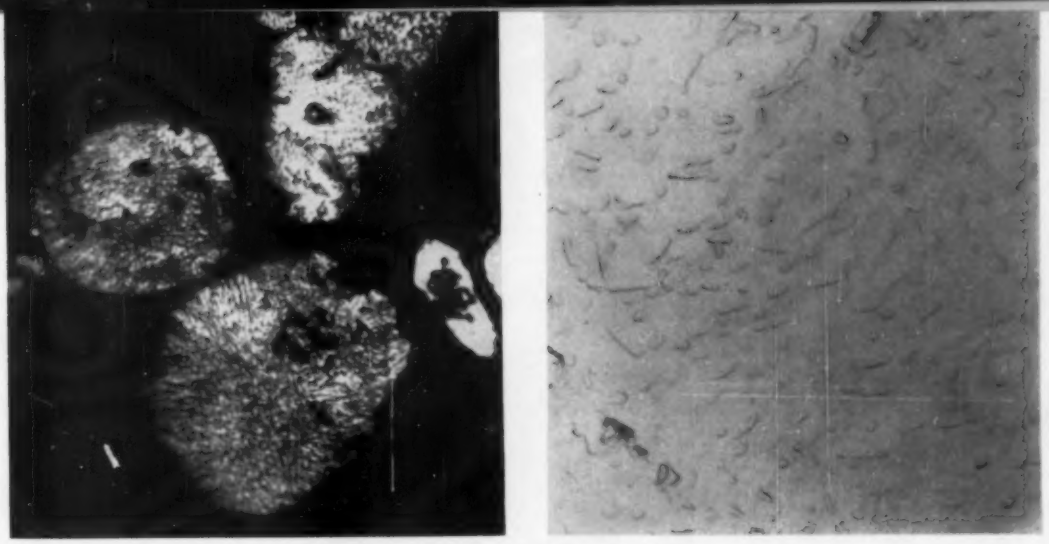


Fig. 1 – (Left) Atomized Aluminum Powder Containing 7.6% Iron. Keller's each; 1000 ×; note typical particle size, shape and fine dendritic structure, poorly resolved at this magnification. At right is electron micrograph at 20,000 × of unetched particle; collodion-carbon replica. Note fine distribution of intermetallic compound

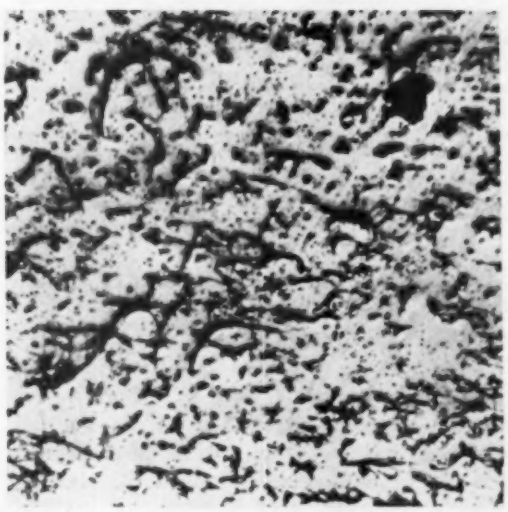


Fig. 2 – Electron Micrograph of Transverse Section of Aluminum Containing 7.6% Iron, Extruded to ¾-In. Diameter Rod. Remnants of the dendritic structure in the atomized powder particles are evident. 20,000 × reduced one half in reproduction

obtains the desired and extremely fine dendritic structure in the powder particles and, therefore, a fine distribution of constituent. In the atomizing operation very small molten particles, ranging around 25 microns in diameter, are quenched in a surrounding atmosphere. Fabrication by compacting and extrusion breaks up this cast structure in the powder particles to some extent and further increases the fineness of dispersion. Furthermore, the constituent particles will be relatively insoluble in aluminum if the alloying elements have been chosen judiciously. Since this type of material has a built-in dispersion of relatively insoluble constituent, further heat treatment after fabrication is neither necessary nor advantageous. Also, a finer and more uniform dispersion may be obtained by atomizing an alloy than by mixing together separate powders of aluminum and secondary constituent.

Choice of Alloying Elements – When choosing the alloying elements for atomized powder for high-temperature parts, several factors should be considered. The structural stability of the alloy is important, as mentioned before, to retain the fine dispersion of alloy constituent at service temperatures. Thus, the dispersed phase should have low solid solubility in aluminum. Some additional benefit may be derived, however, by adding other elements capable of hardening by solid solution. A low diffusion rate of alloying elements in the dispersed phase is desirable, so that coarsening of the structure will be very slow. The tendency for smaller particles to dissolve and larger ones to grow is undesirable from the standpoint of structural stability. (Both solid solubility and diffusion rate of the chosen alloying elements may be decreased even further through their mutual interaction.) Lastly, a high solidus temperature is desirable because it raises the useful service range while, on the other hand, a low liquidus temperature is desirable for ease of atomizing.

Several of the heavier elements, such as iron and chromium, meet some of the requirements listed above and, furthermore, when combined with aluminum they form intermetallic compounds of fairly low density. Thus, appreciable amounts of alloying elements may be added

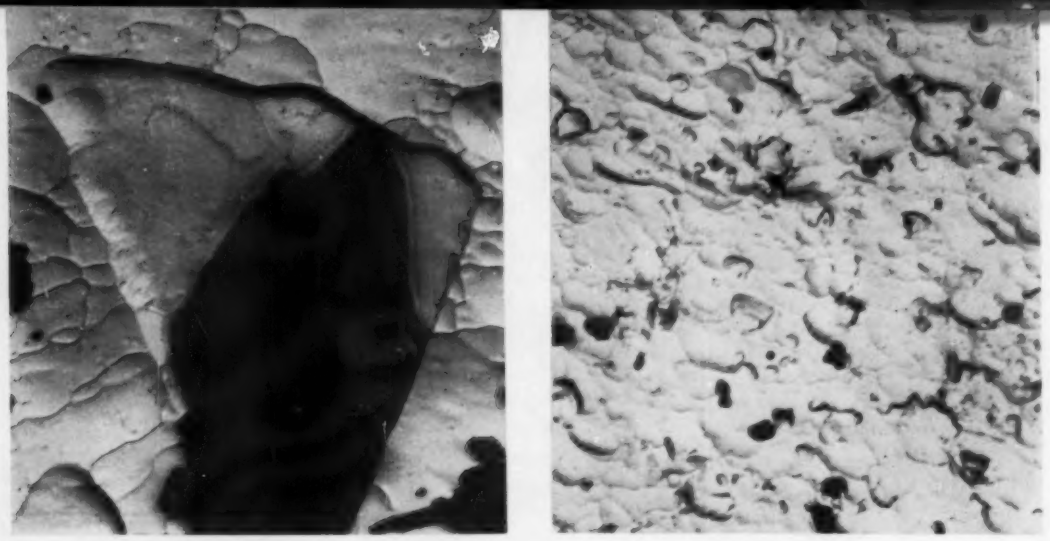


Fig. 3 – Electron Micrographs of Aluminum Containing 4% Iron, Extruded, Cold Rolled 90% and Heated 16 Hr. at 750° F. R-5 etch; oxide replicas, 15,000 ×. Dark areas represent $FeAl_3$ phase. Metal at left originated as cast ingot; note complete recrystallization. Metal at right originated as atomized alloy powder; no recrystallization

Table I – Yield (1000 Psi.) at Room Temperature; 96-4 Al-Fe

Cold Reduction	Extruded Ingot		Extruded Powder	
	As Cold Rolled	Reheated*	As Cold Rolled	Reheated*
None	8.4	7.9	24.1(18%)†	22.7(17%
10%	15.6	6.4	30.7	23.8
30	19.3	5.9	33.8	27.8
50	20.7	6.6	32.3 (9%)	28.3 (10%)
70	21.3	6.5	34.9	29.0
90	22.2	7.4	34.2 (3%)	28.8 (6%)

*Heated 16 hr. at 750° F.
†Numbers in parentheses indicate % elongation in 2 in.

without a prohibitive increase in the density of the final product.

Structure – A photomicrograph at 1000 × of 92.4-7.6 Al-Fe atomized powder particles is shown at left in Fig. 1. The typical size and shape are indicated, accompanied by the extremely fine dendritic structure which is not resolved well even at 1000 diameters. An electron micrograph reproduced at the right at 20,000 diameters shows the fine distribution of the $FeAl_3$ phase.

Screen analyses indicated that roughly 75% by weight of each powder we used would pass through a 200-mesh screen and 50% through a 325-mesh. The average particle diameter was about 25 microns.

The cast structure of the powder particles was broken up somewhat by compacting and extruding. The resulting microstructure was extremely fine. An electron micro (Fig. 2) taken at 20,000 diameters of a transverse section of a ¾-in. round of the 7.6% Fe alloy shows only remnants of the dendritic structure from the powder particles. The average particle size of the dispersed $FeAl_3$ phase is approximately 0.1 micron, and the average distance between particles, surface to surface, is about 0.6 micron. (These values may be compared with those for the oxidized aluminum flake products frequently containing 5 to 17% oxide dispersed throughout the matrix, wherein the average particle size of the dispersed oxide phase may be as much as one order of magnitude less, but the average distance between particles is of the same order of magnitude in both types.)

After heating the 92.4-7.6 Al-Fe material 100 hr. at 800° F., the $FeAl_3$ particles agglomerate slightly, and their average size is increased to about 0.15 micron and the distance between particles to 0.9 micron.

Figure 3 compares the structure of a 96-4 Al-Fe alloy fabricated from tilt mold ingot and from powder. The ingot and the powder compact were first extruded into ¼ × 2-in. strip, cold

Table II – Yield Strength as Affected by Recrystallization

	0.2% Fe	1.7% Fe	4.0% Fe
Cold rolled 90%	25,800	28,700	34,200
Heated 1 hr. at 1000° F.	7,400	9,200	20,400
Recrystallization	Complete	Complete	None

Table III – Mechanical and Physical Properties of Extruded Rod

	Elements Added to Atomized Aluminum					Comparison Alloys	
	Fe-Ni	Fe	Complex M 486	Fe-Cr	Fe-Cr-V	M 257	X 2219-T6
Composition						8% Al_2O_3	
Iron	4.5	7.6	7.8	5.5	2.5		
Chromium	—	—	0.2	5.0	0.4		
Nickel	7.0	—	—	—	—		
Vanadium	—	—	0.2	—	3.4		
Titanium	—	—	0.2	—	—		
Zirconium	—	—	0.2	—	—		
As extruded (70° F.)							
Tensile	68,700	45,500	48,300	56,800	43,800	37,000	62,000
Yield	60500	31,400	34,100	44,300	31,400	24,000	43,000
Elongation*	3.5	16	15	1.0	14	17	16
At 600° F. (100 hr.)							
Tensile	20,900	21,900	24,300	27,100	20,500	17,000	20,000
Yield	14,500	17,800	20,800	20,300	16,700	15,000	15,000
Elongation*	15	19	16	4	18	13	25
At 600° F. (1000 hr.)							
Tensile	20,700	21,900	23,600	26,700	20,800	17,000	18,000
Yield	14,800	17,700	19,700	21,000	17,400	15,000	14,000
Elongation*	11	19	19	3.2	17	13	27
At 800° F. (30 min.)							
Tensile	7,000	10,900	13,400	11,800	10,700	12,000	4,000
Yield	4,400	8,200	10,800	8,400	8,400	11,000	3,500
Elongation*	31	29	20	11	28	5	65
At 800° F. (100 hr.)							
Tensile	7,200	10,100	14,000	12,000	11,300	12,000	4,000
Yield	4,900	7,800	10,800	7,400	8,700	11,000	3,500
Elongation	34	28	23	9	18	5	65
Stress for rupture at 600° F.							
10 hr.	—	14,000	18,000	13,000	13,000	13,000	12,00
100 hr.	—	12,000	16,000	11,000	11,000	11,500	9,000
1000 hr.	—	10,000	13,000	9,000	9,500	10,000	6,500
Creep stress for							
1% in 100 hr. at 600° F.	—	10,000	13,000	9,000	9,500	11,000	7,500
0.5% in 10 hr. at 600° F.	—	10,000	14,000	9,500	10,000	12,000	9,000
0.2% in 1 hr. at 600° F.	—	9,000	13,000	9,000	9,000	11,000	10,000
Modulus of Elasticity							
At 70° F.	12.8×10^6	11.4×10^6	11.7×10^6	12.5×10^6	11.8×10^6	10.6×10^6	10.5×10^6
At 600° F.	—	8.2	8.8	9.0	8.5	7.6	—
At 800° F.	—	5.7	6.4	6.3	5.9	6.6	—
Density at 20° C.	2.95	2.88	2.89	2.91	2.82	2.74	2.82
Electrical conductivity†	31%	42%	26%	<25%	25%	51%	33%
Thermal conductivity‡	0.29	0.39	0.26	<0.25	0.25	0.46	0.32

*% in 4 diameters †At 25° C. ‡At 25° C., C.G.S. units.

rolled 90% to 0.025 in. in the extrusion direction and then heated 16 hr. at 750° F. The heating completely recrystallized the ingot material (Fig. 3 at left), but caused only partial recovery in the powder material. Both figures show the network of lines in the aluminum matrix brought out by the R-5 chemical polishing treatment, as previously described by Hunter and Robinson, in *Transactions* of the A.I.M.E., Vol. 197, 1953, p. 717. It is evident that the $FeAl_3$ particles represented by the dark areas are much coarser in the ingot material than in the powder material, although both samples have been cold worked severely. X-ray diffraction results indicated that this heating caused recrystallization in the strip made from *ingot* but only partial recovery in the strip made from *powder*.

Work Hardening, Recovery and Recrystallization

After the atomized alloy powder and the tilt mold ingot, both with 4% iron, were extruded into strip and cold rolled various amounts, tensile

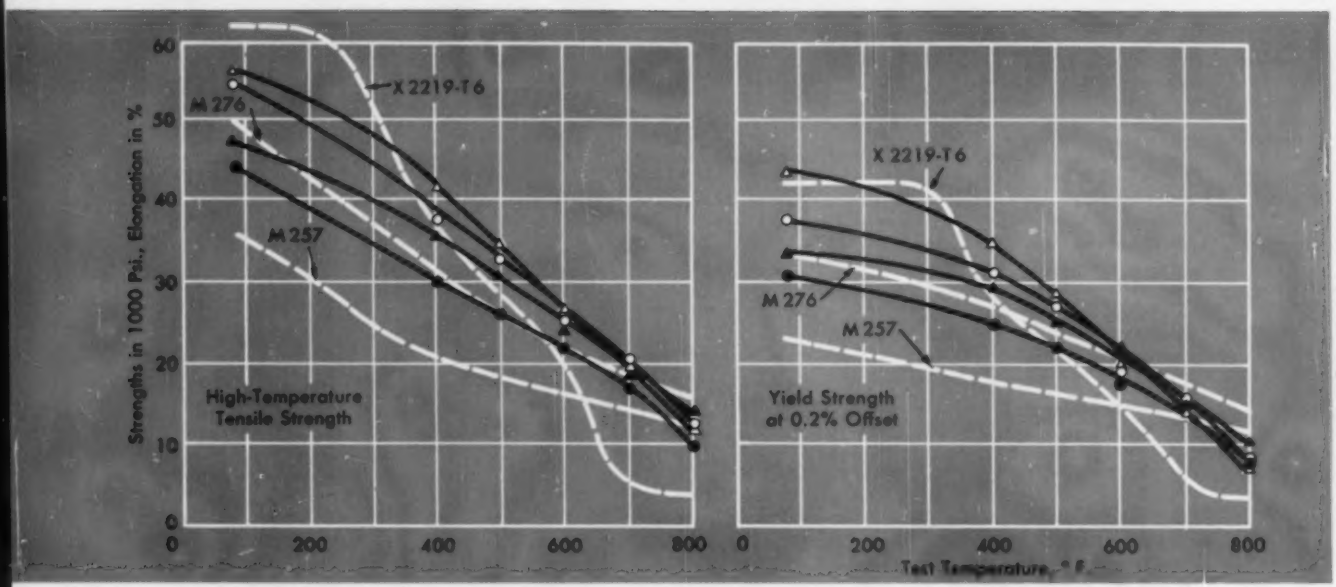


Fig. 4 — High-Temperature Properties of Extruded Rods of Four Promising Atomized Alloy Powders. Also shown are M 257 and M 276 (8 and 13% Al_2O_3 respectively) and the experimental alloy from ingot X 2219-T 6

tests at room temperature in the longitudinal direction appraised the work hardening and annealing characteristics. The much finer dispersion of $FeAl_3$ phase is responsible for a higher tensile strength in the powder material. Table I shows that the yield strength of the powder material is also much higher both in the as-rolled condition and after heating 16 hr. at 750° F.

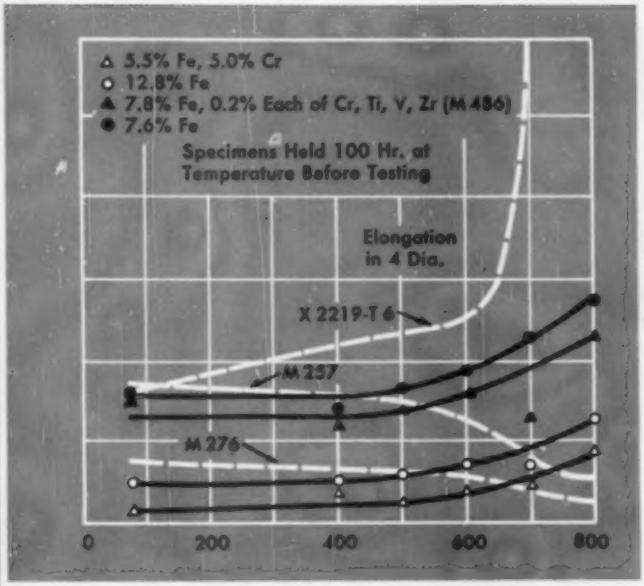
Similar data on work hardening (yield strength at 0.2% offset versus percentage of reduction) for atomized powders containing various amounts of iron indicate that all of them reach maximum strength after about 50% cold rolling, at which time their yield strengths are as follows: 0.2% Fe, 21,100 psi.; 1.7% Fe, 30,000 psi.; 4% Fe, 32,300 psi.; 7.6% Fe, 44,000 psi.; 12.8% Fe, 45,000 psi. It is interesting to note that the 12.8% Fe alloy extruded strip was able to stand a cold reduction of 50% without severe edge cracking.

Recrystallization did not occur in any of these powder alloys after cold rolling and heating at 750° F. for 16 hr., even though the iron content was as low as 1.7% in one instance. The amount of recovery which occurs during heating decreases as the iron content is raised. Heating caused practically no change in the tensile properties of the 12.8% Fe alloy; as cold rolled 50%, its tensile strength was 55,400 psi., yield 43,500 and elongation in 4% 2 in. After being heated 16 hr. at 750° F., the respective figures are 52,000, 42,900 and 6%.

Strip made from powder with various iron contents was cold rolled 90% and then heated at 1000° F. for 1 hr. As shown in Table II, this completely recrystallized the material containing small amounts of iron (0.2% and 1.7%), while the 4.0% alloy showed no evidence of recrystallization. Recrystallization reduced the yield strength by about 70% in both the low-iron alloys; the 40% reduction in yield strength in the unrecrystallized 4.0% alloy resulted from recovery and, to a small extent, from coarsening the alloy constituent. Cold rolling the strip even 30%, instead of 90%, was sufficient to cause complete recrystallization at 1000° F. with iron contents of 0.2% and 1.7%. It thus appears that the iron content should be kept above about 2.5% when the powder product is to be used at elevated temperatures.

The investigation was extended to study the behavior of the 96-4 Al-Fe composition at higher temperatures. For this purpose, strip that had been previously cold rolled 90% was heated at 1100° F. It did not recrystallize during the first hour, but did show evidence of partial recrystallization after 100 hr. The ¼ × 2-in. extruded strip of other atomized powder alloys containing substantial amounts of alloying elements, such as 6.9% Cr, and 4.5% Fe plus 1.1% Co, was cold rolled 90% and heated 1 hr. at 1100° F., without recrystallization.

From these results, it appears that the atomized



powder alloys containing large amounts of iron or chromium resist recrystallization even after cold reductions of 90% followed by heating at temperatures close to the melting temperature. Thus, the atomized powder alloys of high alloy content can be expected to remain strong at elevated temperatures.

Preferred Orientation – From a study of the (111) pole figures it was concluded that the degree of preferred orientation in 90% cold rolled strip of extruded aluminum powders containing 1.7, 4.0, and 7.6% iron would decrease markedly as the iron content increased.

In general, it can be said that both the Al-Al_2O_3 type and the atomized alloy powder product tend to take on a preferred orientation of crystallites during mechanical working. In both varieties the degree of preferred orientation decreases as the number of finely dispersed hard particles increases and the distance between them decreases. These data on preferred orientation, as well as on tensile properties, indicate how effectively the dispersed particles interfere with slip in aluminum.

Particle Size – Decreasing the size of the atomized powder particles measurably increases the tensile and yield strength of extrusions made from them. The reason for this is that the dendrite size decreases with decreasing powder particle size because of the greater rates of cooling and solidification. A finer dispersion of hard phase in the aluminum matrix is obtained, therefore, after compacting and extrusion.

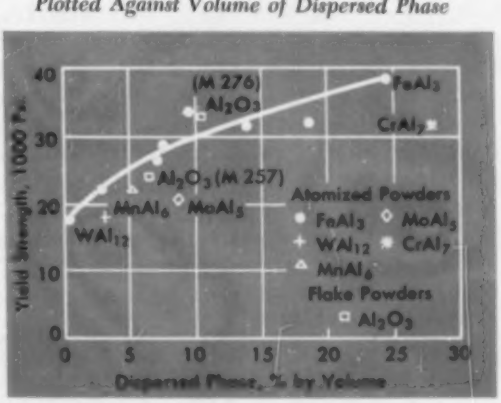
Mechanical Properties

Tensile properties at 70, 600, and 800° F. are given in Table III for a few representative atomized powder alloys (out of many compositions tested) when extruded into 0.75-in. rounds, together with properties of APM alloy M 257 (8% Al_2O_3) fabricated from unalloyed flake powders of high oxide content, and X 2219-T 6 (6.0% Cu, 0.3% Mn, 0.10% V, 0.15% Zr) fabricated in the conventional manner from cast ingot. The alloy with 4.5% Fe and 7.0% Ni had the highest strength at room temperature (68,700 psi. in tension). Those having the best tensile properties at 600 and 800° F. were the iron alloys (7.6%, 10.0% and 12.8%), the complex alloy with 7.8% Fe and 0.2% each of Cr, Ti, V, Zr (M 486), the 5.5% Fe plus 5.0% Cr alloy and the quaternary alloy of aluminum with 2.5% Fe, 0.4% Cr, and 3.4% V. The tensile strengths of these alloys at 600° F. were all 20,000 psi. or better and over 10,000 psi. at 800° F. Tensile data from high-temperature tests after 0.5, 100, and 1000 hr. at 600° F., and 0.5 and 100 hr. at 800° F. show little change with time at temperature, indicating that the alloys have good structural stability.

Strength and elongation at 600° F. of the complex alloy M 486 are better than the extruded flake product M 257; M 486 is stronger than alloy X 2219-T 6 made from ingot at 600 but has somewhat less elongation. M 257 has better strength but much lower elongation than any of the atomized aluminum alloys at 800° F.

Tensile properties are plotted against test temperature (100-hr. stay) for extruded rod of four promising atomized powder alloys in Fig. 4. Also included are results for APM alloys M 257 and M 276, and X 2219-T 6 fabricated from cast

Fig. 5 – Room-Temperature Yield Strength of Rod Extruded From Different Powders Plotted Against Volume of Dispersed Phase



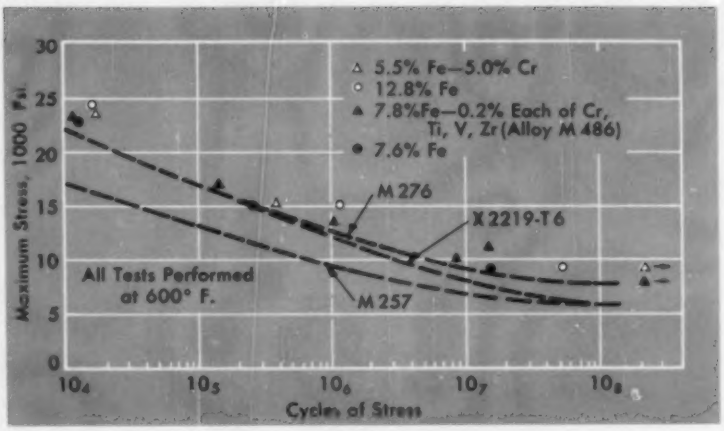


Fig. 6 – Cantilever-Beam Fatigue Test Results at 600° F. for Extruded Rods

ingot. From about 400 to 700° F., three of the plots for strength of the new alloys are above those for M 257, M 276 and X 2219-T 6. Of these three the complex alloy M 486 has the highest elongation – 23% at 800° F. It should be noted that even the remaining atomized powder alloy containing 7.6% Fe has higher strength and ductility in this temperature range than M 257 with 8% oxide. Probably the most useful combination of strength and ductility, though, is possessed by M 486 alloy, which has good strength all the way up to 800° F.

The atomized powder product enjoys an advantage over the SAP and APM type, represented by M 257 and M 276, since its ductility does not decrease with temperature. In fact, the elongation of the new alloys actually increases with temperature – as is normally true for conventional aluminum alloys. Added ductility is beneficial in meeting service specifications and in hot working operations.

Yield strength at room temperature is plotted against per cent by volume of dispersed phase for aluminum-iron and other alloys in Fig. 5. The yield strengths of the atomized powder binary alloys containing manganese, tungsten, molybdenum, and chromium all fall below the curve for the aluminum-iron binary alloys whose hardening phase is $FeAl_3$. The phenomenon is now under study but it is suggested that it is due to a finer dispersion of $FeAl_3$ particles (closer together and of greater number but smaller size). It is interesting to note that the oxide type of powder alloy, M 276 (13% Al_2O_3) has a yield strength above the curve for the iron hardened products, while that of M 257 (8% Al_2O_3) is below the curve. When tensile properties of aluminum-iron alloys at 600° F. (after 100 hr.) are plotted against the per cent by volume of $FeAl_3$, the dispersed phase, the marked increase in strength with increasing amount of $FeAl_3$ is due to the increased number, rather than size, of dispersed particles.

Stress-rupture data at 600° F. are also presented for four of the atomized powder alloys in Table III. The complex alloy M 486 has the highest values, and they are above those for the comparison alloys M 257 and X 2219-T 6. Values for total creep at 600° F. show that M 486 again is the best of the atomized powder alloys, and is better than M 257.

Cantilever-beam fatigue tests at 600° F. for smooth specimens are plotted in Fig. 6 for four atomized powder alloys and the points are equal to, or above, even those for M 276.

The large amounts of iron and chromium are beneficial in another important respect, for they produce a high modulus of elasticity in the alloy, as compared with 9,900,000 psi. for wrought commercially pure aluminum.

Densities and electrical and thermal conductivities of the atomized powder alloys are also given at the bottom of Table III. It may be noted that appreciable amounts of heavy elements were added without a prohibitive increase in density over commercial purity aluminum (2.71 g. per cc.). This is attributed to the presence of the alloys as intermetallic compounds of much lower density than the elemental metals.

Conclusions

1. The mechanism of dispersion hardening may well be used to strengthen aluminum alloys by atomizing, compacting, and extruding powders containing relatively large amounts of iron and other alloying elements. Fabricating products from powder compacts, rather than from cast ingots, is a more practical method with certain alloy systems because, no matter what the size of compact, a fine uniform dispersion of alloying elements and small dendrite size will be obtained. When the alloying elements are rela-

(*Continued on p. 176*)

Underground Atomic Explosions*

A nuclear device equivalent to 1700 tons TNT was detonated deep underground in a mesa or butte at the Nevada Test Site on Thursday morning, Sept. 19, 1957. Observers at a forward area about 2½ miles away saw a ripple on the side of the mesa as the shockwave moved upward. A few felt a slight movement in the earth under their feet, but most felt nothing. Clearly visible were spurts of dust rising from the hillside where rock was being dislodged from the mesa crown. No radioactivity was released into the air.

It was suggested some years ago that underground testing of nuclear devices would have certain important advantages over bursts in open air. Among these were total absence of fallout, absence of blast and flash effects off-site, and no interruption to air traffic. Proper instrumentation of new types would be necessary, for when a nuclear device is detonated in air, photographic and other measurements can be made of the growth of the fireball, and samples of the fission products can be readily captured for radiochemical analysis.

Scientists from the U.S. Geological Survey recommended the site and supervised two preliminary underground shots, one of 10 tons and the other of 50 tons TNT, and scaled up the results to locate, properly, the 1700-ton explosion. An advisory panel of seismologists and geophysicists reported that the shock would not "trigger" an earthquake nor cause any off-site property damage – likewise that the possibility of ground water contamination was very remote.

A 6 × 8-ft. tunnel was driven 1900 ft. into the mesa, ending in a "button hook". The small chamber for the device was therefore located so the nearby tunnel end would be closed by blast effects before any energy manifestations could travel around the "hook" and escape through the entry.

Subsequent exploration showed that 200 ft. of the tunnel was sealed by rock. This region centering on the explosion was explored by core drilling with equipment designed for remote operation against the possibility of penetrating a high-pressure region – which, in fact, did not occur. Horizontal drilling from within the open tunnel was aimed directly at the point of detonation, and about 100 days after the detonation encountered zones of relatively high radiation 100 ft. away. The normal rock temperature was 63° F., and 60 ft. from ground zero a rock temperature of 113° F. was encountered. Subsequent drilling to points below the point of detonation revealed temperatures as high as 190° F. A maximum radiation reading of about 45 roentgens per hr. was recorded at about 50 ft. below ground zero.

From such observations as these, it was concluded that the detonation had created a spherical cavity and that for a very brief time the rock around its circumference had melted so that in effect a "glass ball" about 110 ft. in diameter existed. The weight of the shattered rock above this glass ball quickly crushed the sphere and rock fragments filled the cavity. The falling rock created a cavity which was encountered in vertical drilling operations 385 ft. above the detonation.

General Conclusions – The special instruments located in and around the shot chamber operated successfully. A nuclear detonation not only can be contained deep underground, but diagnostic and other necessary measurements can be obtained successfully. In fact, certain experiments which require good collimation and massive shielding can best be accomplished underground. Shots with much larger yield could be fired in a deep underground chamber with little or no resulting air contamination and with no seismic hazard. Practically all of the fission products were trapped in highly insoluble fused rock so ground water is not contaminated.

Peacetime Applications – The underground shot produced at least 50,000 tons of permeable broken rock and an additional 400,000 tons of crushed but relatively impermeable rock. These large masses suggest its use in mining to break up ore bodies for removal or for leaching in place, and in oil strata to free crude oil trapped in relatively nonporous rock formations, or to heat heavy hydrocarbons so they drain away as liquid.

Other possibilities include piping water into a rock formation heated by a contained nuclear detonation to form steam for producing power or process uses; placing various materials around a device to be detonated deep underground to change them through nuclear reaction; to investigate the earth's crust through seismic studies of resulting earth waves; and moving earth in quantity, such as in digging a large canal.

*From information released by U.S. Atomic Energy Commission, March 6, 1958, entitled "Background Information on the Deep Underground Shot (Rainier) at the Nevada Test Site".

Coming: Better Thermenol Alloys

*By W. J. BUEHLER and C. G. DALRYMPLE**

Iron-aluminum alloys with 3 to 4% Mo have excellent oxidation resistance and stress-rupture strength. With small additions of zirconium and carbon to raise the mechanical properties and inhibit the grain growth, the alloys are useful for many high-temperature applications.
(Q-general, P-general; SGA-h, Fe, *Al*)

ALUMINUM has a number of varied and valuable effects when added to iron and its alloys. In very small amounts – 0.002 to 0.004% – it is the universal deoxidizer for fine-grained killed steels. Certain steels with 1 to 2% Al comprise some of the Nitralloys – alloys designed specifically for nitriding. In larger amounts – here we quote† – "aluminum improves the resistance to oxidation more effectively than equivalent amounts of chromium. It also increases high-temperature strength and decreases the density of such alloys." This combination of properties indicates that iron-aluminum alloys might be useful for some high-temperature applications – compressor blades and missile skins are two examples. In 1952, the Naval Ordnance Laboratory launched an investigation which resulted in the Thermenol alloys. With 10 to 18% Al and 2 to 4% Mo in an iron base, these alloys have several interesting properties:

1. Favorable density due to high aluminum contents.
2. Excellent elevated-temperature oxidation resistance.
3. Good stress-rupture and tensile strength at elevated temperatures.
4. Corrosion resistance to many corroding media.
5. Soft magnetic characteristics similar to certain nickel-base alloys.
6. High electrical resistivity.

These characteristics, together with the fact that the alloys require no critical or strategic elements, means a promising future for the Thermenols. Two preferred types were developed: a standard composition with 16% Al and 3.3% Mo, and a modified composition with a similar base plus minor additions of zirconium and carbon.

Preparation of Standard Thermenol

Since much information has already been published on the Thermenol alloys, this article will scan only the more recent advances. (Readers desiring a detailed account of past work will

*United States Naval Ordnance Laboratory, Silver Spring, Md.

†"Fe-Al-Mo Alloys for High-Temperature Use," by J. F. Nachman and W. J. Buehler, *Metal Progress*, December 1956, p. 107.

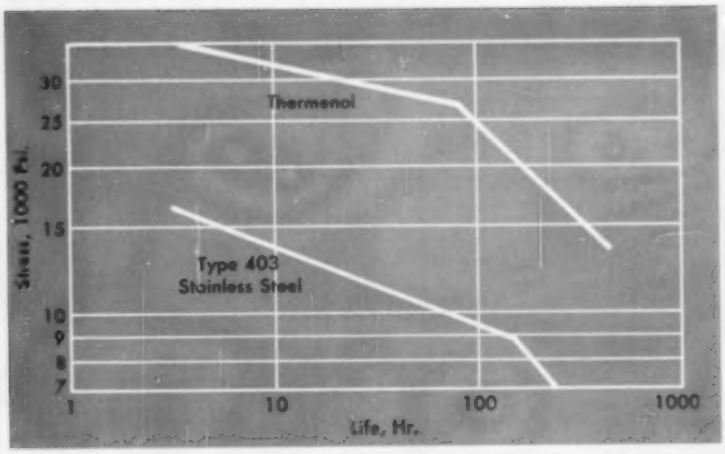


Fig. 1 – Stress-Rupture Curves for Standard Thermenol and a Typical Stainless Steel. The testing was performed at 1200° F. (Courtesy Thompson Products, Inc.)

find some references at the end of this article.)

We have discovered that these alloys are best melted by induction in a vacuum or a controlled atmosphere. In controlled-atmosphere melting, hydrogen is used to purify the iron. After this operation, helium replaces hydrogen, and the melt is poured. In vacuum melting, carbon is added to purify the iron. However, when the alloys are for magnetic application, hydrogen purification is preferred; residual carbon is detrimental to the magnetic properties.

Finished cast shapes of various types, as well as ingots for further processing, have been satisfactorily produced by standard casting techniques. The cast grain size and shape vary with the rate of solidification and the addition of grain-refining elements such as boron and mischmetal.

The castings can be surfaced in a variety of ways: Alloys with less than 12% Al machine adequately. With alloys containing more aluminum, grinding (using a copious supply of coolant) is required because of the rapid work hardening. The ingots can be forged, swaged, rolled, and extruded readily above 1750° F.; the lack of scaling at high temperatures aids these operations appreciably. Patented* methods for warm drawing and rolling (1020 to 1110° F.) produce a more ductile wire and sheet. Cold forming, necessary for magnetic applications, is possible; best results are obtained when the aluminum content is less than 12%.

Table I gives some of the physical and mechanical properties for standard Thermenol alloy. The alloy also possesses quite remarkable oxidation resistance at elevated temperatures. At 2200° F. the surface loss is only 0.0003 in. per yr.; this is better than the oxidation rate of any other known high-temperature alloy system. Figure 1 shows the stress-rupture curves for Thermenol and Type 403 at 1200° F. As is evident, Thermenol is considerably better, particularly up to 100 hr. where the stress is 25,000 psi. in comparison to 9500 psi. for stainless steel.

Development Program

Despite the many advantages, the standard Thermenol possessed two drawbacks which caused many fabrication difficulties and greatly limited its usefulness. Being a single-phase alloy, the grain growth was very rapid at elevated temperatures (Fig. 2.). Since the alloy also had low ductility at room temperature, it was obvious that some improvements were in order.

Under the U.S. Navy Bureau of Aeronautics

Table I – Some Properties of Standard Thermenol

Density	6.58 g. per cc.
Thermal conductivity	6.3 Btu./sq. ft./hr./°F./ft.
Coefficient of thermal expansion (68 to 1300° F.)	11.0×10^{-6} in./in./°F.
Recrystallization temperature	1380° F.
Electrical resistivity (room temperature), ordered	150 microhm-cm.
Electrical resistivity, disordered	170 microhm-cm.
Lattice type	b.c.c.
Tensile strength	80,000 psi.
Elongation	2 to 3%
Modulus of elasticity	26×10^6 psi.
Rockwell hardness	C-30

*U.S. Patent 2,768,915.

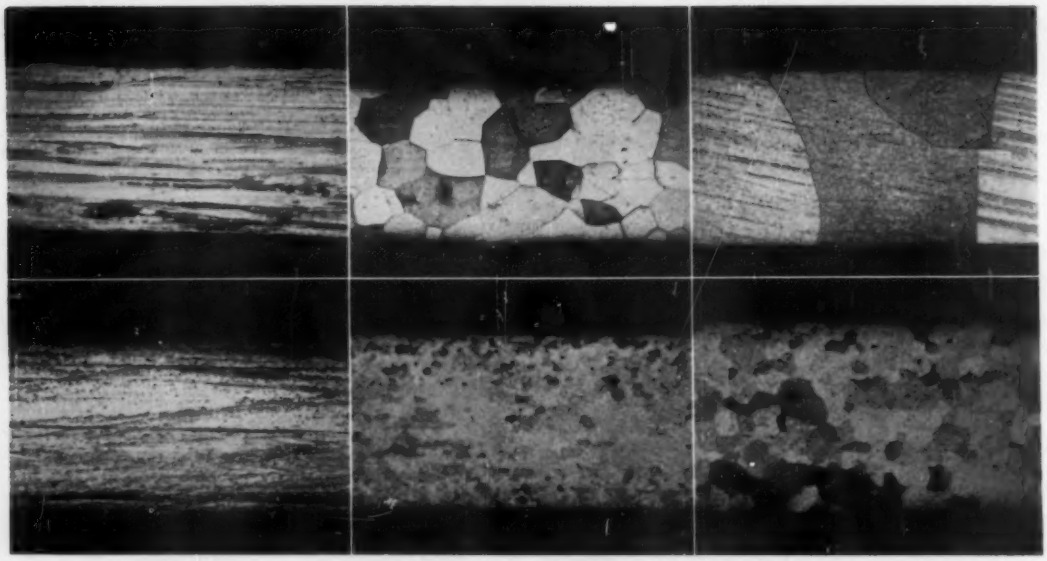


Fig. 2 – Grain Growth in Standard Thermenol (Above) and Modified Thermenol. From left to right, the specimens were heated to 1300, 1650 and 2000° F.

sponsorship, the campaign began with the consideration of four metallurgical factors and their effects on the resultant alloys. These were:

1. Effect of minor alloying additions on the base alloy.
2. Effect of order-disorder variations on mechanical properties.
3. Effect of various heat treatments on mechanical properties.
4. Directionality of mechanical properties.

The minor additions studied were those that could "clean up" the alloy and concurrently inhibit the grain growth. Considerable investigation proved that small quantities of carbon and zirconium, when added together in amounts which varied from 0.05 to 0.10% and from 0.2 to 0.4%, respectively, produced startling results. The alteration in grain growth characteristics is illustrated by Fig. 2.

Since these alloys exhibit ordering, order-disorder studies were performed to determine the effect of this transition upon the mechanical properties. With electrical resistivity measurements being used to determine the degree of ordering, sheet tensile specimens were heat treated to produce atomic orderings varying from 0 to 100%. Complete disorder was effected by heating the specimen above the ordering range (1157° F.) and quenching in water to room temperature. Cooling very slowly from above 1157° F. to room temperature resulted in 100% order. The variation in electrical resistivity due to atomic ordering is given in Table I. Tensile test results showed that specimens almost wholly disordered exhibited the best elongations.

Heat treatments of cold worked sheet cause variations in the degree of ordering and recrystallization (depending on the temperature). By proper heat treatment (keeping these two considerations in mind), the best over-all mechanical prop-

Table II – Tensile Properties of Modified Thermenol*

Specimen	Warm Reduction	Heat Treatment†	Elongation	Tensile Strength
1	89%	1337° F., 1 hr.	4.0%	107,700 psi.
2	89	1337 1	9.0	117,800
3	84	1337 1	10.5	129,000
4	84	1472 ½	9.0	126,000
5	89	1337 1	7.0	128,700
6‡	60	1337 2	9.0	121,800
7§	60	1337 2	8.0	115,500

*Specimens 1 through 4 contained 0.2% Zr and 0.05% C; specimens 5, 6 and 7 contained 0.4% Zr and 0.1% C.

†Specimen 1 was cooled in the furnace; the rest were oil quenched.

‡Orientation parallel to rolling.

§Orientation transverse to rolling.

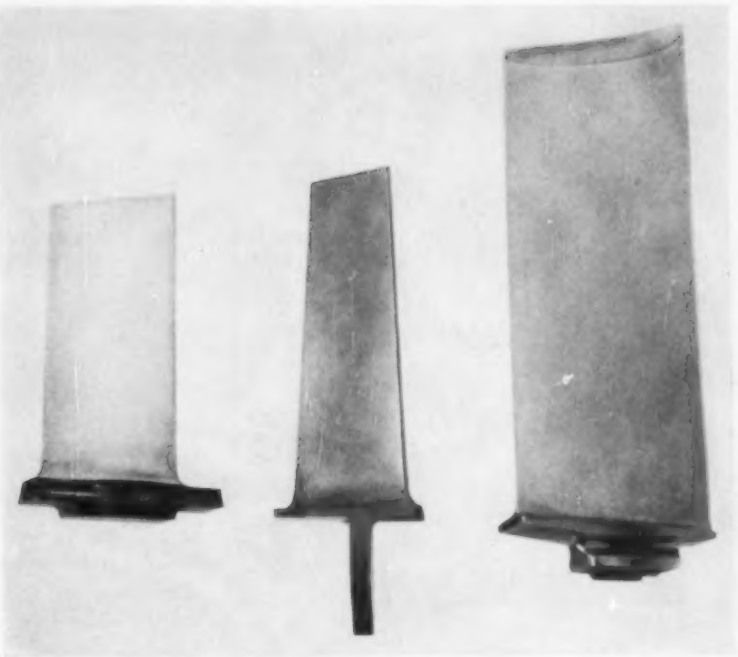


Fig. 3 – Jet Engine Compressor Blades Produced From Thermenol. (Courtesy Thompson Products, Inc.)

erties were obtained from a structure with a minimum recrystallized grain size and a disordered condition. Minor variations in the carbon and zirconium and the maximum heat treating temperature (providing it is not too high) have almost negligible effect upon the mechanical properties. Table II illustrates these effects; it is also apparent from these data that little if any mechanical anisotropy exists.

The minor change in alloy composition and the carefully contrived heat treatment have resulted in a more versatile Thermenol. With its higher ductility, higher tensile strength and lower ductile-to-brittle transition temperature, the sheet will be easier to fabricate into usable products. The effect of zirconium and carbon in stabilizing the grain size at elevated temperatures should aid in maintaining a finer grain size in the heat-affected zones of a weld.

Future of Iron-Aluminum Base Alloys

The iron-aluminum base materials have had their ups-and-downs since the turn of the century. Alloy development research was greatly hampered by the inability to produce high-purity materials and suitably process these into usable forms. In the present era with the availability of good quality melting stock, high-purity melting (on a commercial scale), warm rolling, and hot extrusion techniques, many of the past deterrents have been eliminated.

The transition of these alloys from a laboratory curiosity to commercial production is a major step that is just now being initiated. Engineering problems will undoubtedly arise, but when the rewards are sufficient, almost any difficulty can be overcome. We offer the successful pilot plant production of jet engine compressor blades shown in Fig. 3 as an example.

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A Look at High-Frequency Resistance Welding

By WALLACE C. RUDD*

In addition to welding the old stand-bys, steel, aluminum, and copper, it is claimed that the high-frequency process will join dissimilar metals, reactive metals, and thin-walled stock better and faster than ever. The welding current penetrates scale and oxide layers. (K3)

HIGH-FREQUENCY electrical energy for seam welding of tubes and strip is a new adaptation of the old idea of causing current to flow across a metallic joint, to heat it to the melting point and join the surfaces together. In the newer technique, the current reverses at a very much higher rate – 450,000 cycles per sec. compared to line frequency of 60 cycles. It does not follow a direct low-resistance path between two contacts; rather, it follows a very long path, the low inductance path. This is shown schematically in Fig. 1 where the return conductor is located close to the path of the current. The current inherently flows next to itself; that is, it flows in a path as close to the return conductor as possible.

By following this circuitous path, the heating rate on either side of the weld joint can be varied independently (an asset when joining dissimilar metals). Also, the shallow depth of the inductance path produces high-intensity heating in shallow zones, and results in a minimum of heat-affected metal. Oxide coatings are no longer a barrier to welding.

The New Rochelle Technique – The patented method developed by New Rochelle Tool Corp. is based on these high-frequency resistance heating principles. Contacts are placed on either side of two abutting edges of metal. The edges touch at one end and the rest of the joint is opened slightly so the gap forms a sharp Vee (Fig. 2). The current flowing from one contact hugs the surface of one edge of the Vee as far as the root (the weld point) and completes the circuit by returning along the opposite edge of the Vee to the second contact. This skin effect produces localized high-intensity heating so the edges at the root of the Vee reach welding temperature at the same rate as the strip progresses through the welding machine. Pressure applied at the root of the Vee brings the two edges together in a forge weld.

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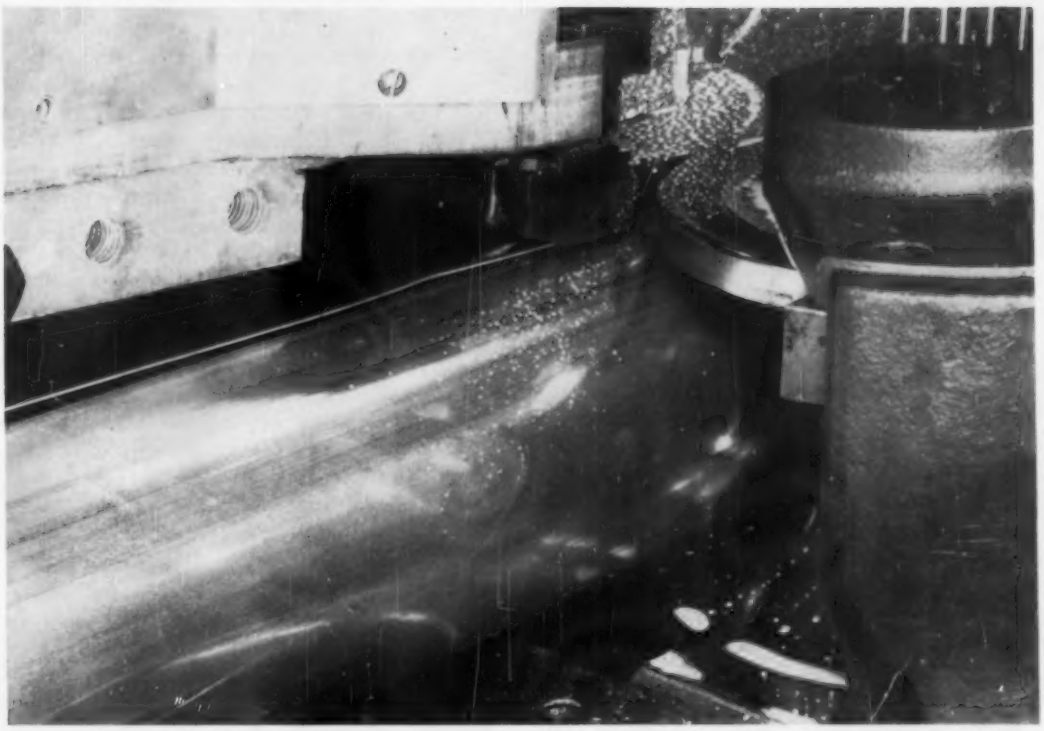


Welding Section of a 6-In. Aluminum Tube Mill. High-frequency contacts and squeeze rolls are shown. Coolant is soluble oil

This is a perfect example of high-frequency resistance heating. Each side of the Vee acts as a return conductor for the other, since the tendency of the current (flowing in the lowest inductance path) is to flow on the two surfaces of the material next to each other. These are the two surfaces being welded.

The abutting edges of metal establish a sliding or rolling electrical connection with the two contacts. Wear is no problem since the contacts touch the metal lightly and are water cooled. The oxide films on the metal surface act as a high-frequency conductor by virtue of their peculiar properties at high frequency. That is, the contacts do not establish a direct connection with the parent metal; their first light contact is with the oxide coating. Thus a minimum of pressure is required. Contact life on aluminum is from 200,000 to 400,000 ft. and on steel is from 50,000 to 100,000 ft. of tube.

In conventional electric resistance welding, low-voltage, low-frequency, high-amperage current is applied to the two sides of the pieces to be welded. Heat is developed by contact resistance between the two edges. Contact resistance is a function of the resistivity, pressure,

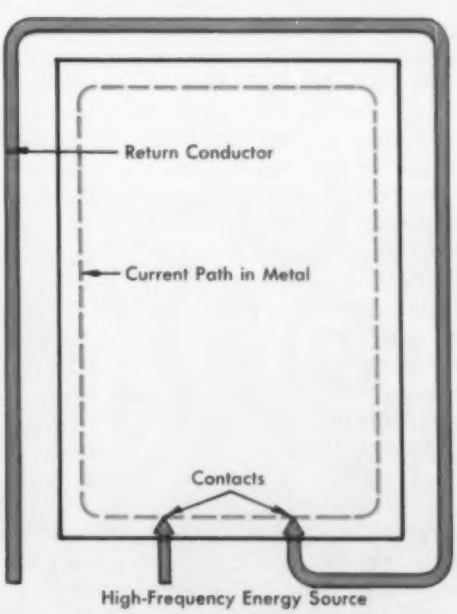


Fig. 1 – Schematic View of Low-Inductance Circuit

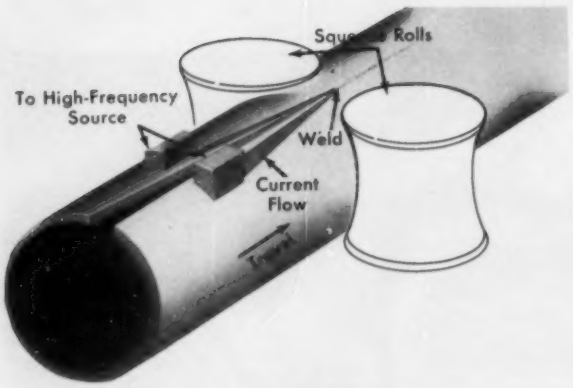


Fig. 2 – Working Section of High-Frequency Resistance Welding Unit. High-frequency current heats metal to welding temperature at the same instant the squeeze rolls pinch the moving edges of tubing together

area, and other variable factors such as surface condition. With the high-frequency resistance welding process, the two pieces are heated *without* being in contact with one another, and only when they have reached welding temperature are they pressed together to form a forge-type weld.

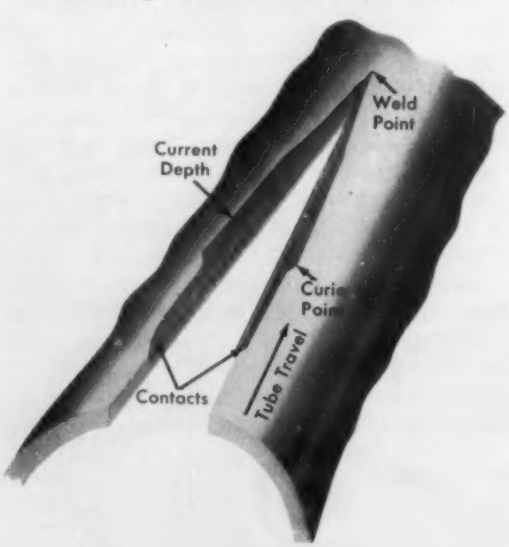
Depth of Heating – With high-frequency resistance heating, the current path can be controlled but necessarily varies to some extent with different metals. Most of the magnetic materials being welded have a Curie point (loss of magnetic properties) at about 1300° F. The current, on leaving the contact and approaching the weld point, at first passes through cool metal, below the Curie point. In this region in steel, for example, the depth of penetration is about 0.004 in., heating the skin intensely. In metal hot enough to have reached its Curie point, the current travels through material which is nonmagnetic but which has a higher resistance. Depth of penetration increases and current flow may go as deep as 0.030 in. As the current continues to flow toward the weld point, it is more and more affected by the return current flow on the other side of the very narrow Vee; therefore, as it gets nearer to the weld point, the depth of penetration becomes less due to the proximity or enhanced effect of the return conductor. Thus there is a maximum of heating effect near the weld point. This is vividly demonstrated in a static test in which the tube being welded remains stationary and heat is applied momentarily. The melted zone occurs around the weld point. Figure 3 represents depth of current from edge backward.

In nonmagnetic materials, the current penetration depends upon resistivity and proximity. It might reach as much as 0.030 in. in copper but as the current flows toward the weld, its resistance increases due to the increased temperature and proximity effect and, under such conditions, it travels at less depth in the material. Consequently, the heating intensity becomes greater as the section approaches the weld point.

Because the metals are pinched together at the point of the Vee, molten material, if present, is squeezed out (upset) and the internal weld becomes essentially a forged weld. Since heat penetration beyond the surface is no more than a few thousandths of an inch, the heat-affected zone is very shallow. One of the important advantages of the process is its adaptability – the fact that the same welding head can be used with equal ease on a large variety of metals with a change only in the power input or the speed at which the metal is welded. The equipment and power supply for producing the welds are identical. The speed of welding is independent of tube diameter and is only dependent upon the wall thickness.

Upset – In producing a weld, two abutting edges are brought to welding temperature and then pressed together. The pressure between the two governs the size and location of the upset, which in turn governs the quality of the weld. If the pressure is light, the weld will be

Fig. 3 – Current Depth Pattern of High-Frequency Welding Unit. Heat penetrates only a few thousandths of an inch



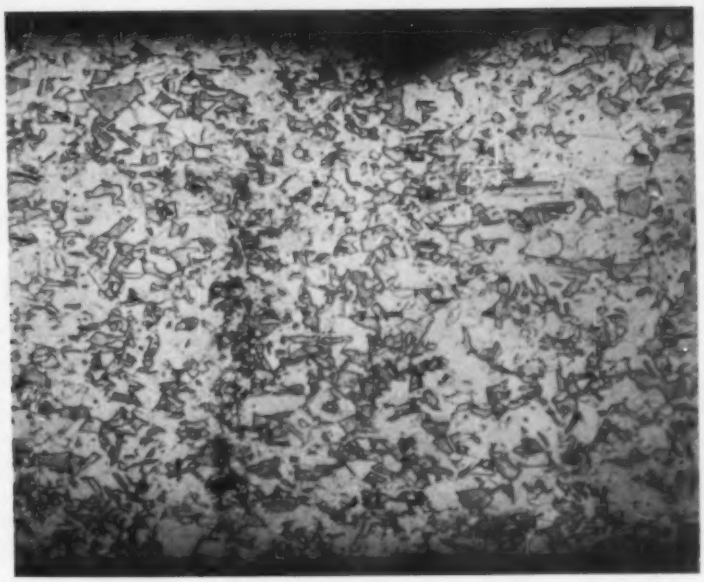


Fig. 4 – Electrolytic Tough Pitch Copper. Grain size unchanged in the weld zone. Etchant: $Na_2Cr_2O_7$, 150 ×

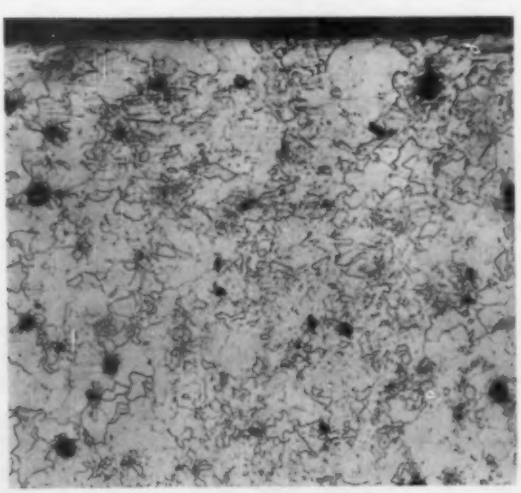
poor; if the pressure is heavy, the weld is usually good if the temperature is correct. With a high pressure, some of the metal is moved or upset.

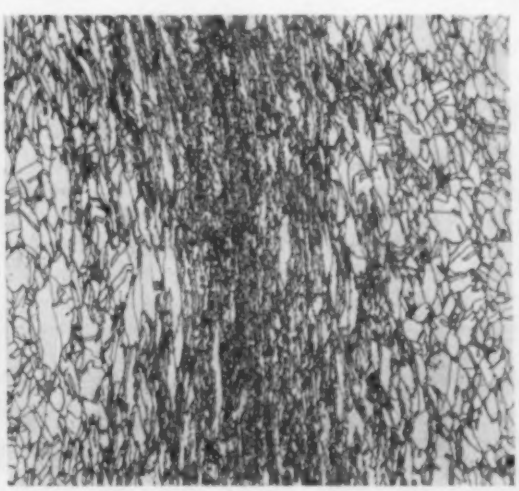
The upset can be controlled (*a*) by magnetically causing the current to flow either up or down the face of the edges being welded, or (*b*) by scarfing the edges. In the latter instance, if the two nearest edges (lands) are on the upper side, these will be hotter than the inner ones and the upset will go upward. The converse is also true. The slant of the edges can be cut on the strip as it enters the mill by the normal trimming cutters.

Magnetic control is established by placing magnetic material next to the Vee. This changes the inductance and corresponding reactance, and so controls the flow of current. These controls are extremely important when a minimum of internal bead in a tube is desired.

Aluminum, Copper and Brass – Aluminum and copper have low resistivity and high thermal conductivity. They have not been effectively welded with low-frequency resistance welding

Fig. 5 – Microstructures of Welded Hot Rolled and Stainless Steel. On the left, hot rolled unscaled European steel, etched in Nital, 100 ×; on the right, Type 302 stainless steel, annealed and etched electrolytically in 10% oxalic acid





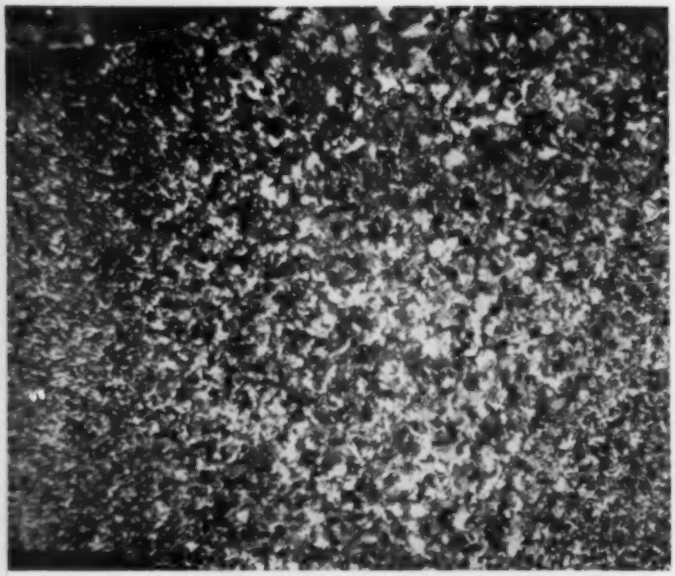


Fig. 6 – Effect of Welding 0.045-In Wall Zircoloy-2 Tubing. 50 ×

equipment. But with high-frequency equipment, these properties are no hindrance. Consequently, a large variety of aluminum tubing made of various alloys has been welded successfully in ranges from ½ to 10 in. in diameter. Copper having a conductivity as high as 101% has been very successfully welded without change in grain size at or near the weld. Microstructure of a weld in tough-pitch copper is shown in Fig. 4.

Brass has often been considered difficult to weld because of its natural tendency to lose zinc when hot. A shielding atmosphere is usually required, but with high-frequency resistance heating this is not necessary. The high resistivity of brass makes it very weldable at high speed, and this speed, in turn, leaves insufficient time for dezincing.

Steel – The process also is well suited to the welding of many types of steel. (About 50% of today's installations are for steel.) Scaled hot rolled steel can be welded without difficulty, and segregated steel is no problem. Hot rolled pickled and cold rolled steels are easily welded. Stainless in the 300 and 400 series also can be handled by the high-frequency process. Photomicrographs of various welds in steels are shown in Fig. 5.

Zirconium – Zirconium and Zircoloy have also been welded quite successfully when protected by an argon atmosphere. They are welded at fairly high speed, in order to keep the heat-affected range at a minimum. Structure of Zircoloy, as welded, is shown in Fig. 6.

Many other materials have been welded successfully, such as bronze, silicon bronze, german silver, and Inconel. Typical speeds for various wall thickness of tubing made of aluminum, copper and steel are given in Table I.

Welding Dissimilar Metals – High-frequency resistance welding is not limited to the manufacture of tubing; two strips can be welded with equal ease. More than that, two strips of dissimilar material can be joined. One unusual application is welding high speed steel to high-carbon steel at 50 to 100 ft. per min. These two materials have entirely different resistivities, magnetic properties, thermal properties, and plastic ranges, and therefore will reach welding heat at different temperatures. It is necessary to control the temperature in one of them. This is done with magnetic reactance devices which deflect the current in the high speed steel, increasing skin effect heating, which establishes a suitable differential. An example: welding of band saw blades where the teeth are of high speed steel, and high-carbon steel is used as a backup.

Table I – Typical Welding Speeds for Tubing Using a 50-Kw., 450-Kc. Welding Unit

	Speed, Ft. per Min.		
Thickness	Aluminum	Copper	Steel
0.010 in.	500+	320	500+
0.025	500+	220	300
0.035	300	180	225
0.062	190	75	130
0.081	110	—	100

Thin Metals – The process is particularly adaptable for joining very thin strip or sheet ranging from 0.004 to 0.020 in. thick. The big problem is usually alignment or register of the edges. (With high-frequency resistance welding, a lap weld can be made.) Contact (electrode) pressure on the seam is so light that it creates no problem.

Thick metals up to ¼ in. have been welded satisfactorily, and it should be practical to weld up to ⅜ in. wall thickness. Thick pieces sometimes require a device to preheat the edges to about 1000° F., if insufficient welding power is available. By using this technique, welding speeds can be nearly tripled.

Electric Furnace Refractories

*Reported by E. C. WRIGHT**

Refractory slurries are poured into forms around electrode parts; self-curing mixes are made with additions of silicon metal powder and sodium silicate whose reaction generates enough heat to set and dry the rammed refractory. (B19, D5; RM-h)

ONE OF THE FEATURES of the Electric Furnace Steel Conference, held in Pittsburgh early last December by the Metallurgical Society, A.I.M.E., was a session wherein five important papers were presented on the general topic of refractories. What follows will state the highlights of this meeting.

Cast Refractories – J. D. McCullough, chief engineer of the Refractories Div., Babcock & Wilcox Co., discussed "Cast and Rammed Sections in Arc Furnace Roofs", and he pointed out the advantages of "casting" a section into the furnace roof, rather than allowing for electrode openings by intricate and costly brickwork. He described monolithic refractories of three different types:

1. Plastic refractories carrying approximately 45% alumina and having a density of 165 lb. per cu.ft.

2. Ramming mixes having from 65 to 83% alumina with densities of 175 to 180 lb. per cu.ft.

3. Two castable refractories. One is stable in volume to 3000° F., contains 60% alumina and has a density of about 125 lb. per cu.ft.; the second is stable to 3200° F., contains 66% alumina, with density of about 135 lb. per cu.ft.

Experience over more than two years with the first of these castable refractories around the electrode ports indicated that the average roof life was increased 33% – from 60 heats for a roof made of silica brick to 80 heats for one with cast ports. At the end of the campaign the cast refractory projected a couple of inches beyond the adjacent silica brick – in other words, it was more heat resistant than conventional roof.

The brickmason foreman then changed from silica roof brick to "superduty clay brick", retaining the castable refractory around the electrode ports. This increased roof life to about 100 heats, with no patching. Again, roof life was determined by the approaching failure of the brick rather than of the electrode ports.

Forming the three ports is quite simple. A metal collar about 22 in. diameter is appropriately located for each electrode. Silica roof brick are laid up in complete rings until they come within about 6 in. of these collars. Three partial rings are then laid between the ports, leaving a 6-in. space between brick and collar. After the third partial ring is laid, the brick are then laid at right angles to their former direction and carried in this manner up to the center of the roof, where the three "spokes" meet to form a triangle. This triangle and the spaces around the collars are then filled with the castable refractory. This procedure eliminates time-consuming cutting and fitting of individual brick.

The dry castable is mixed with about 16%

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water for easy placement. This is a somewhat higher percentage than would give maximum strength, but since the mixture is superior to the surrounding brick, it does not matter. About 2400 lb. of dry mix is used in each roof.

Overnight curing is by wet sacks, placed after the mixture has taken its initial set. The roof then air dries until a furnace is ready – from 24 hr. to a week later. A new roof does not need to be babied on the first heat.

Canadian magnesite is available from two large deposits in Quebec. Although their qualities are quite different, satisfactory basic refractories have been produced from each. As pointed out by A. H. Thomson of Canadian Refractories, Ltd. (Montreal) usage in Canada closely parallels that in the United States.

A newly burned magnesite brick having about 85% MgO content and maximum density for this class of product soon proved to be superior at the slag line where the brick must resist basic slag. Magnesite and chrome, chemically bonded, has been favored in the upper walls, provided the bricks are encased in steel. The steel – even though thin – is an excellent conductor and acts as a cooling system which reduces spalling, as well as strengthens the entire sidewall.

Basic refractories now used in Canadian electric furnaces are as follows: *(a)* upper sidewalls – nonspalling magnesite, steel encased; *(b)* slag line and lower sidewalls – 85% magnesite brick; and *(c)* door arch – chrome-magnesite, or nonspall magnesite between MgO ramming mix.

Tar-bonded basic refractories were discussed by G. P. Holt of Basic, Inc., Cleveland. These are basic minerals mixed with 5 or 6% of coal tar, molded, and then packaged in waterproof paper for shipment.

Three types of such brick have been used in Europe for many years although they have been given little attention in the United States. These are *(a)* magnesia plus tar, *(b)* dolomite plus tar, *(c)* mixtures of dolomite and magnesia plus tar.

The first mentioned is the most expensive but it is also the most reliable since it does not hydrate in storage; it can also be used for furnace linings, particularly for oxygen-blown converters.

Dolomite should be used promptly. Long storage causes it to disintegrate due to hydration of the lime it contains.

The magnesia constituent of these tar-bonded refractories has a composition typical of the dead-burned grain magnesite which might be used to make magnesite brick. Ground magnesia is also commonly used for the fine fractions mixed with the coarse bodies in dead-burned dolomite. (Adequate densities require carefully proportioned mixtures of coarse and fine particles in both brick and ramming mixes.) Ground particles of dead-burned dolomite react rapidly with moisture in the air and seriously hydrate within a few hours. This does not occur to dead-burned grain magnesite.

Coal tar pitch must be used as binders on account of its coking characteristics. Upon heating, a large proportion of it vaporizes, leaving a carbon residue which acts as a bond for the brick, enabling it to resist spalling at intermediate temperature. Thus the most important quality of each tar is its coking characteristics. Heavy coal tars have much more favorable coking characteristics than do substances like asphalt; most of the asphalt volatalizes without leaving behind any bond.

Ladle Refractories – A paper on self-baking refractory mixes (especially for ladles) was presented by L. A. Stoyell of Electro Metallurgical Co. and T. R. Culbert of Case Institute of Technology, in which they emphasize that thorough drying of thick sections of rammed refractory usually means a long period of time, a drying oven, or a gas or an oil flame. Wet rammed refractory can now be rapidly and thoroughly dried when a self-baking refractory mix is used. Aside from the desired refractory material, the basic ingredients of this mix are silicon metal powder and an alkali metal silicate which react and generate sufficient heat within the rammed mix to set and dry it completely.

The silicon metal powder has 95% minimum purity in particles through 200 mesh, and the sodium silicate is commercial grade. Different refractory ingredients include silicon carbide, silica sand (with and without silica flour), magnesite mix (periclase and dead burned magnesite), and zircon sand. The self-baking reaction, if not spontaneous, can be initiated within a minute by a gas flame directed on one spot.

A minimum amount of silicon metal powder is required for satisfactory strength for each particle size distribution of a refractory. As the porosity (or coarseness) of the refractory increases, the required percentage of silicon metal increases. Silicon carbide refractories of this sort have density (after self-baking) of 105 to 120 lb. per cu.ft. and compressive strength of about 1200 psi. The figures for silica sand are 107 and 1650 psi., respectively, and for the magnesite mix, 140 lb. per cu.ft. and 2670 psi. compressive strength.

A Study of Temperature Uniformity in Heat Treating

By HAROLD N. IPSEN*

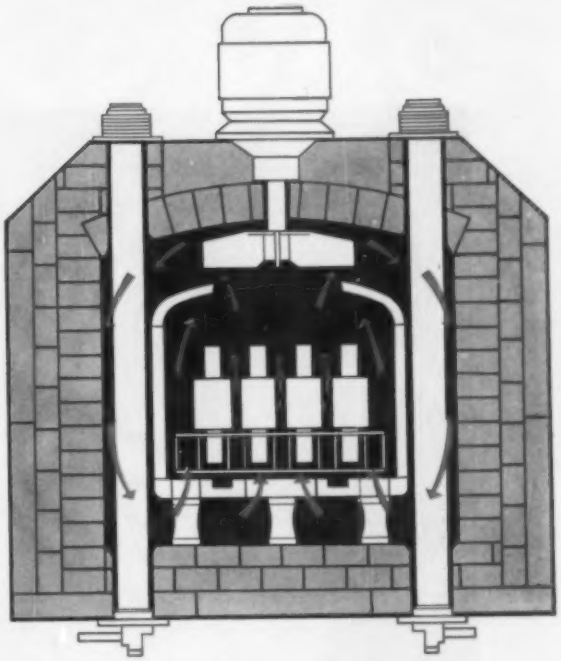

Fig. 1 – Arrangement of Baffle and Fan in the Test Furnace

Tests were made with and without forced convection to study variations in temperature reached by parts in center and edge of a work basket of steel stampings. Nonuniform heating can result in appreciable difference in the structure and properties of heat treated parts. (J28, P11k, W27n; ST)

TEMPERATURE UNIFORMITY is an important factor in heat treating. Variation as insignificant as plus or minus 25° F. (U.S. Air Force Specification No. 303) may be sufficient to prevent full hardening of a part. Uniform heating is essential where sections are nonuniform and where heavy machining stress is involved.

The degree of incomplete hardening that can be tolerated depends on the type of part. It is generally considered desirable that bolts and other parts subjected to substantially uniform tensile stresses be at least 90% martensitic. Aircraft fasteners require complete hardening for acceptance.

For applications involving high-carbon and alloy steels (normally subjected to heavy service loads), a full hardened structure becomes increasingly important. In a spring application, ability to resist a permanent set depends on full hardening. Maximum hardening of alloy steels depends on complete solution of carbides, and requires higher temperatures and longer cycles. This is especially true of steels containing appreciable amounts of Cr-Mo-V which precipitate large carbide compounds. This condition is exemplified in tool and die applications which must be heated uniformly to temperatures up to 1950° F. under close temperature control. While preheating is often considered essential, it is not required if the part is brought to soak temperature uniformly.

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Case Hardening Processes

Temperature uniformity is especially important in case hardening because it controls the

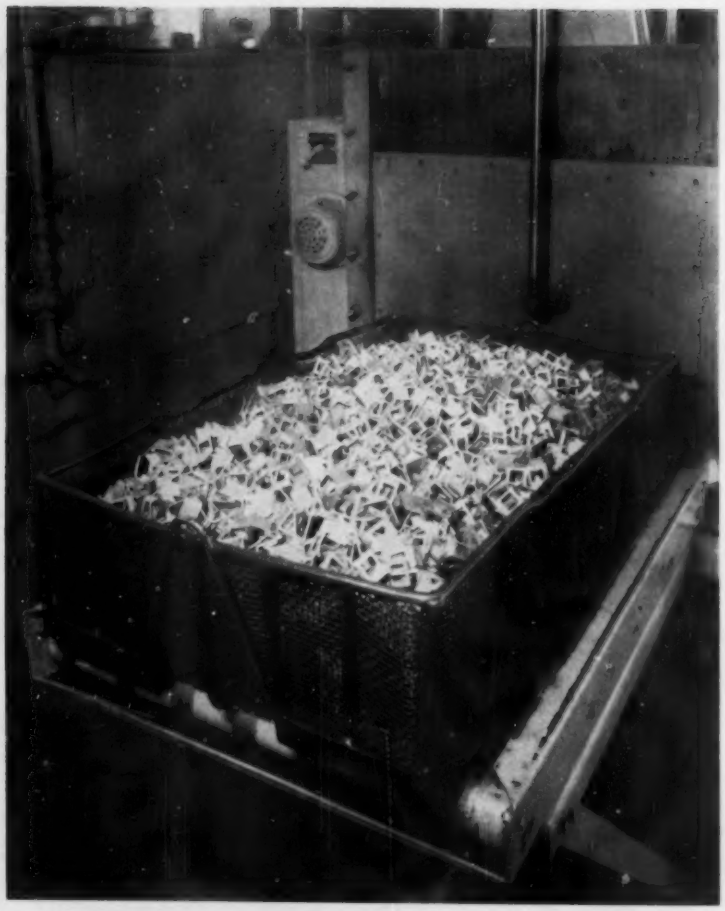


Fig. 2 – A Standard Work Basket Containing 557 Lb. of B 1112 Steel Stampings for Bathroom Scales Was Used in the Tests. A thermocouple was welded to a part in the center of the basket, another to a part near the side, 6 in. from the floor

depth of penetration and carbon concentration. Critical core properties and requirements for minimum amount of retained austenite call for restricted temperature ranges. Ammonia introduced into the atmosphere in the carbo-nitriding process increases the rate of penetration and solubility of carbon in the austenite matrix, and further reduces allowable temperature variations.

This example shows the specific relationships of time-temperature and case penetration: A maximum variation of 1650 to 1700° F. within a furnace will cause a spread of 0.050 to 0.060 in. in case depth in a normal 5-hr. cycle. It would require an additional 2 hr. carburizing time for the maximum case at the lower temperature. For case depths in the range of 0.120 in., additional time needed would be about 10 hr.

Another factor is involved in carbo-nitriding. Computing machine and typewriter components have extremely thin sections which must be held to a maximum case of 0.001 to 0.002 in. If the temperature varies more than ± 15° F., it is impossible to meet this requirement – even at temperatures as low as 1400° F.

The case-core relationship also influences the service effectiveness of a part. Close control of both structures must be maintained, especially on highly stressed parts such as ring gears, drive pinions, and transmission gears.

The secret of a good case is the degree of compressive stress in the surface layer. In most applications the prime importance of the core is to support the case, assuming that the core structure is of sufficient strength to resist bending or torque loads. In certain applications, such as sheet metal screws, this latter requirement is critical. It presents a temperature control problem because a short heat cycle with a controlled soak at the maximum carbo-nitriding temperature (1650° F.) is required for complete core hardness. In most gear applications grain coarsening due to overheating must be controlled; otherwise surface compressive stresses may be substantially reduced.

To a limited degree, the effect of heat variables within a load reverses the tool heat treater's trick of restoring concentricity or straightness to a section by localized heating. Uneven heating induces stresses. Parts with irregular cross sections and extensions are most susceptible to stress concentrations.

Tests Measure Variations

Forced-circulation convection heating at temperatures above incandescence is more effec-

tive in controlling case depth, uniformity, and distortion than is generally realized. Experimental work was performed to prove this point. The results led to the application of the principle of 100% forced convection heating in all Ipsen equipment. Equipment used was the controlled atmosphere furnace illustrated in Fig. 1. The hearth area is 24 in. wide, 36 in. long, with an 18-in. effective working height. The hearth floor is perforated with uniformly spaced openings equal to one third of its total area. Demountable baffle sidewalls are lightweight but solid, and the arched roof has a 14-in. square center opening. Above the roof opening is a 19-in. diameter centrifugal fan driven by a 3-hp., 1750-rpm. electric motor. Eight vertical ceramic heating tubes, with flame busters, provide a maximum hourly input of 464,000 Btu. Heated atmosphere circulates through each of the hearth openings at a velocity of about 2400 ft. per min.

A standard work basket containing 557 lb. of B 1112 steel stampings (Fig. 2) for bathroom scales was used in the tests. The gross load was 600 lb. A thermocouple was welded to a stamping and inserted in the center of the loaded basket. Another part with welded thermocouple was placed near the side of the basket load, 6 in. from the floor bottom.

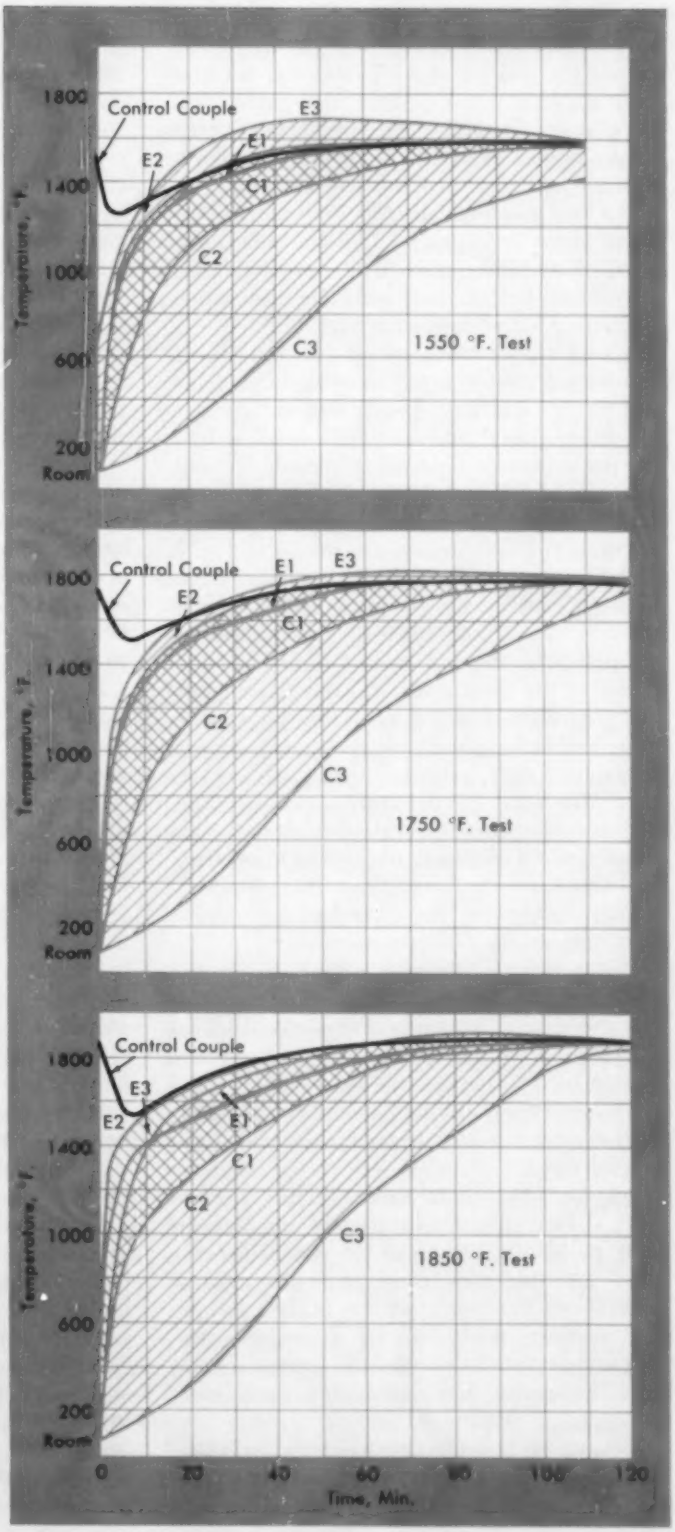


Fig. 3 — Charts Show Temperature Reached by Center Part (C) and Edge Parts (E) under These Three Test Conditions: 1. With directional flow baffle and 19-in. fan circulation. 2. With 14-in. fan, without baffle. 3. Without muffle, without fan. Tests were made at 1550° F. (top), 1750° F. (center) and 1850° F. (bottom)

All tests were conducted with controlled atmosphere to simulate production conditions. An endothermic generator was used, cracking natural gas and air at 2.5:1 ratio and automatically controlling to a + 30° F. dew point. The thermocouple lead wires were passed out through an atmosphere vent, which allowed all tests to be made under normal furnace pressures.

The load was tested at 1550, 1750 and 1850° F. under these conditions: 1. With both directional flow baffles and 100% fan circulation. 2. Without baffles, but with fan circulation. 3. Without either fan or baffles.

In each test, the furnace was held at temperature for sufficient time to insure equilibrium. A cold charge was then moved into the furnace, and the recovery time accurately checked from the potentiometer controlling records. Simultaneous checks were made of temperatures at the two locations in the charge, and of the fuel gas consumption. Results are shown in Fig. 3.

The poorest condition for heating was direct radiation, without use of fan or baffles (Condition 3 in Fig. 3). As might be expected, recovery time (the interval from insertion of cold charge to the point where furnace heating system goes off full-fire) is normally longer than under convection conditions, and becomes more pronounced with increased operating temperature. The worst characteristic, however, is the temperature spread through the charge upon completion of furnace temperature recovery. Also noteworthy is the fact that there was substantial overshoot of the control temperature in parts adjacent to radiating surfaces.

The tests were repeated with the use of a 14-in. muddling fan within the heating chamber, over the charge, but without directional baffles (Condition 2 in Fig. 3). Operating at synchronous speed of 1750 rpm., the fan directed atmosphere horizontally outward and vertically downward to pick up heat from the surface of the heating tubes.

Separate observation indicated that a minimum of heated atmosphere came into forceful contact with the bottom of the charge because short circuiting took place at levels substantially above the bottom of the furnace. However, recovery intervals were somewhat better than without the fan and the temperature spread from the center thermocouple to the outside thermocouple decreased.

A standard 19-in. fan replaced the muddling fan and the tests were repeated without baffles. The increased circulation of the larger fan substantially reduced the heating interval and narrowed the temperature spread in the charge.

The final tests studied the effects of guided, high-velocity circulation (Condition 1 in Fig. 3.), using the 19-in. diameter fan and directional flow baffling within the heating chamber. No overshoot occurred because the temperature control thermocouple was in the atmosphere path from the heating tubes enroute to the charge.

Comparison of the hardness obtained by water quenching sections of S.A.E. 1045 steel from 1340, 1380, and 1425° F. gave values of Rockwell C-27, 51, and 58, respectively. On the basis of test results, a theoretical 500-lb. load of S.A.E. 1045 parts austenitized from 1550° F. (Condition 3 on the top chart in Fig. 3) would recover, as indicated by the control couple, in 50 min.

Allowing 20 min. for soak (which would be normal practice), a considerable portion of the load would be under 1340° F. and would not harden. Thus, a 500° F. temperature variation in the basket load would be present at time of quench. Under Condition 1 (optimum circulation), the same work load would be uniformly soaked out, resulting in full hardening.

A typical 0.008 to 0.010-in. case specification would be impossible under Conditions 2 and 3 of the test. A 100-lb. load of small stampings was carbo-nitrided for 1 hr. at 1550° F. in the test furnace. With no fan or muffle (Condition 3) the case was from 0.001 to 0.013 in.; with 14-in. fan but no muffle (Condition 2) it was 0.004 to 0.010 in.; with standard fan and baffle (Condition 1) it was 0.009 to 0.010 in.

The additional case in Condition 3 is attributed to temperature overshoot from radiant heat transfer. The light load allowed faster recovery at the center than noted under test conditions.

The benefit of the guided convection heating lies in the higher heating rate from ambient to control temperature, with emphasis on that portion of the operation from equilibrium between chamber, muffle, and charge up to control temperature.

In this uniform rise, the tendency for equalization is pronounced; thin sections heat at no higher rate than adjacent thick sections, regardless of their position in the charge. The baffle gives directional flow of the heated atmosphere and minimizes direct radiation to parts adjacent to the heating tubes. In addition, the baffles and brickwork provide a convenient reservoir of heat. An appreciable amount of stored heat from their surface may be transferred to the stream of atmosphere for convection heating.

How to Treat Pickle Liquors in a Small Plant

*By EDWARD W. LANG**

A crystallization-regeneration unit at Vulcan Rivet & Bolt Corp., Birmingham, Ala., has solved the problem of disposal of pickle liquors from a 1200-gal. batch tank. The system is based on removing 400-gal. portions of liquor, crystallizing ferrous sulphate for economical disposal and returning regenerated liquor to the tank. (A8b, L12g)

MILL SCALE AND RUST are generally removed from steel by pickling in sulphuric acid. When the ferrous sulphate concentration reaches about 15%, the pickling rate decreases and the spent pickle liquor, containing 3 to 10% sulphuric acid, must be regenerated or disposed of. The disposal of spent pickle liquor has been a problem for many years because almost all methods that do not cause stream pollution are uneconomical, especially for small plants.

Most fabricators of steel use batch pickling, as compared to continuous strip pickling used by steel mills. In the past, the small batch pickling plants had little problem in disposing of the spent liquor. Because the volume was relatively small, it was usually dumped into streams or pumped to storage lagoons. The strengthening of stream antipollution laws has greatly increased the disposal problems. For plants pickling small amounts of steel, the disposal or regeneration methods applicable to large plants are costly. The purpose of this article is to appraise methods of disposal which are practical for the small plant and to describe an inexpensive crystallization unit used by a steel fabricating plant in Birmingham, Ala., to regenerate acid and to produce ferrous sulphate crystals for easy disposal by dumping and covering.

Methods of Disposal

Many plants neutralize the liquor with lime and dispose of the resulting slurry by lagooning. This method has the disadvantages of being costly in equipment and lime; large storage

*Head, Chemical Engineering Section, Southern Research Institute, Birmingham, Ala.

areas for the neutralized product are required. A number of processes with byproduct recovery have been proposed, but none provide sufficient income from the products to defray the operating costs. With small amounts of spent acid for disposal, fabricating plants are more interested in reducing the cost and nuisance of disposal than in recovering byproducts. Methods which have been used by small plants for disposal of spent liquor include:

1. Dumping into streams or underground cavities. The acidity and high ferrous sulphate content make dumping into streams quite objectionable. This means of disposal is usually prohibited by state laws. Disposal underground is an inexpensive alternative, but it may weaken the structure of the ground or may pollute underground water supplies and result in law suits.

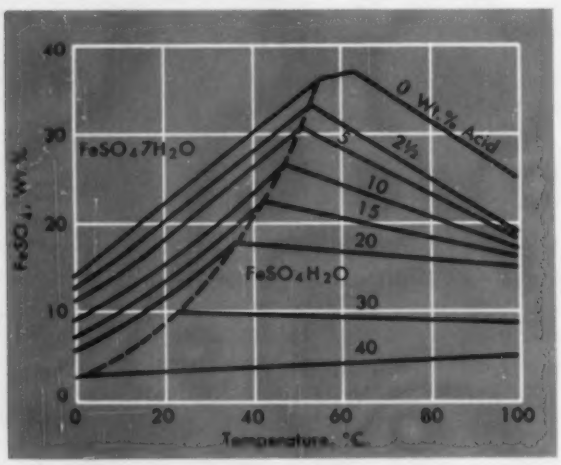


Fig. 1 — The Effect of Temperature and Sulphuric Acid Concentration on Solubility of Ferrous Sulphate

2. Dumping into sewers. The high acidity of the pickle liquor will damage sewers, which forbids this method from being used in most cities. Even if the pickle liquor is first neutralized, it is objectionable because it increases the load to the sewage disposal plant, and plugs sewers and air diffusers in the activated sludge process.

3. Lagooning. This requires large areas and does not overcome stream pollution problems unless the liquor is first treated with lime.

4. Lime neutralization. This is the usual method of disposal. A lime slurry is added to spent liquor to react with the free acid and ferrous sulphate to form insoluble calcium sulphate and ferrous hydroxide. Sometimes these solids are filtered from the neutral solution to give a wet solid which is easier to dispose of. However, filtration is a slow process and adds considerably to disposal cost. For this reason, the neutralized slurry is usually run to lagoons where most of the water drains off. Lagooning is not practical in most locations because of space required. The over-all cost of lime neutralization is normally greater than the cost of the acid used in pickling.

5. Crystallization of copperas. This procedure offers the small pickling plant an inexpensive method. The spent liquor is cooled to cause the copperas (ferrous sulphate) to crystallize out. The crystals are removed and the remaining liquor is recycled to the pickling tank. The free acid is recovered for reuse. The disposal problem is reduced to dumping the recovered crystalline copperas. No lime is needed.

Small Batch Pickling

An investigation was carried out at Southern Research Institute to develop a practical method of disposal for the Vulcan Rivet & Bolt Corp. of Birmingham. This company pickles about 15 tons of steel wire per day in a 1200-gal. tank. A study of the various methods indicated that the crystallization of copperas was the most economical process from the standpoint of investment and operating costs. This method is well suited to plants using batch pickling because a high concentration of ferrous sulphate can be tolerated in the pickle liquor.

Most of the published data on crystallization regeneration deals with continuous pickling where ferrous sulphate concentrations greater than 15% cannot be tolerated because the rate of pickling is decreased. In plants where batch pickling is used, the rate of pickling is of less importance. A sulphuric acid content of 3 to 6%, a ferrous sulphate content of 25 wt.% (34 vol.%), and a bath temperature of 150 to 170° F. will give a satisfactory pickling rate. Because a relatively high concentration of ferrous sulphate can be tolerated in the pickling liquor, cooling to ambient temperatures will remove a reasonable portion of the ferrous sulphate as copperas. In continuous pickling (where it is desirable to maintain the ferrous sulphate at about 15%), refrigeration of the

liquor is necessary to cause more of the ferrous sulphate to crystallize. An alternative is to evaporate the liquor before it is crystallized. Either process is quite expensive.

Solubility of Ferrous Sulphate

The properties of ferrous sulphate-sulphuric acid solutions are given in Fig. 1, taken from Pearson and Bullough (*Journal* of the Iron and Steel Institute, Vol. 167, 1951, p. 439). More recent studies by Kobe and Frederickson (*Chemical and Engineering Data Series*, Vol. 1, 1956, p. 13) substantiate these data. The curves in Fig. 1 show that the solubility of ferrous sulphate reaches a maximum between 50 and 70° C. (122 and 158° F.). The solubility decreases as the sulphuric acid concentration increases. A saturated solution at 60° C. (containing 5% sulphuric acid) will give crystals of the heptahydrate (copperas) if cooled, and crystals of the monohydrate if heated. The concentrations used in this article are given in wt.% whereas many plants express concentrations in vol.%. Vol.% is g. per 100 ml. of liquor; wt.% can be converted to vol.% by multiplying by the specific gravity of the liquor. To aid in this conversion, the specific gravity of pickle liquor at various concentrations of sulphuric acid and ferrous sulphate is given in Fig. 2 from data of Wragge (*Journal* of the Iron and Steel Institute, Vol. 162, 1949, p. 213).

The data in Fig. 1 are useful for determining the desired limits for ferrous sulphate and acid concentration. They also can be used to determine the quantity of pickle liquor which must be removed from the tank and crystallized to maintain the bath at the concentration needed. An example will show how to use these data:

Figure 1 shows that when operating at 150° F. and 2% sulphuric acid, the ferrous sulphate content can be increased to 31 wt.% before copperas will crystallize out. In this case, a safe maximum concentration might be 25 wt.% (33 vol.%). In a batch-type crystallization-regeneration unit, a portion of this liquor is pumped to a cooling tank where the liquor is cooled to 75° F. Make-up acid, equivalent to the ferrous sulphate to be removed, is added before the liquor is cooled so that the solubility of ferrous sulphate is further decreased. This added acid increases the acid concentration to 8.8%. As indicated in Fig. 1, cooling of this liquor to 75° F. (24° C.) causes copperas to crystallize out until the liquor contains 16% ferrous sulphate. In this example, 50% of the original ferrous sulphate is removed as crystals of copperas. The liquor which is drained from the crystals contains the recovered acid and the make-up acid. It is returned to the pickling tank. The amount of copperas which is recovered from a batch pickling plant thus is equivalent to the sulphuric acid added to the pickling tank.

The Plant Unit

Vulcan Rivet & Bolt Corp. operates its 1200-gal. pickling tank at 140 to 160° F. and 2 to 6% sulphuric acid. Ferrous sulphate concentrations up to 25 wt.% are normally used. Pickling

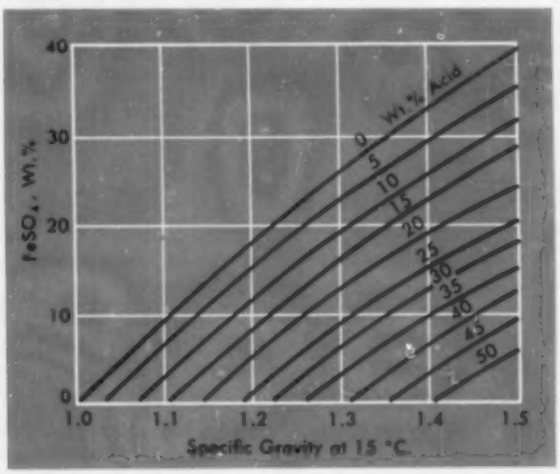


Fig. 2 – The Specific Gravity of Pickle Liquor at Various Concentrations of Sulphuric Acid and Ferrous Sulphate

time of about 30 min. is required for coils of ½ and ¾-in. wire. Design of the crystallization-regeneration unit was based on removing three crystallization batches per week containing 25 wt.% ferrous sulphate. The unit consists of a transfer pump, a cypress crystallizing tank and a cypress holding tank, each having a capacity of 800 gal. The pump is 1½-in. centrifugal type made of Worthite. The holding tank is mounted at a level higher than the pickling tank so that the liquor can be returned by gravity. The crystallization tank is mounted above the holding tank so the liquor can be drained from the crystals to the holding tank. Polyethylene ("Carlon Type EF") flexible pipe was used for transfer piping and for a 2-in. cooling coil in the

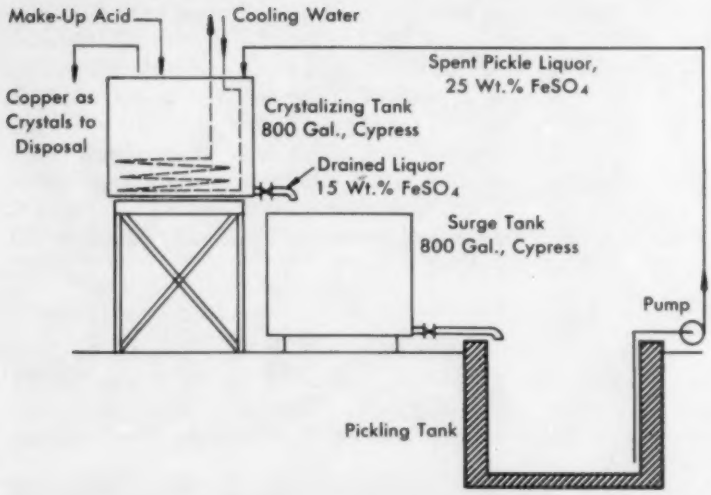


Fig. 3 – Flow Diagram of a Unit for Regenerating Waste Pickle Liquor Suitable for a Small Plant

crystallization tank. (Air cooling was not fast enough.) The installed cost of the plant unit was about $2000.

Operation

The cycle consists of removing and crystallizing three 400-gal. batches per week. This permits the ferrous sulphate content to build up to about 25 wt.% (33 vol.%) before another batch is pumped to the crystallizing tank. About 350 lb. of 66° Be sulphuric acid is added to make up for that lost as ferrous sulphate. The batch is cooled during a period of one to two days to about 70° F. by means of the water cooling coils. The liquor is drained from the crystals to the holding tank. The drained liquor contains approximately 15 wt.% (18 vol.%) ferrous sulphate and 9% sulphuric acid.

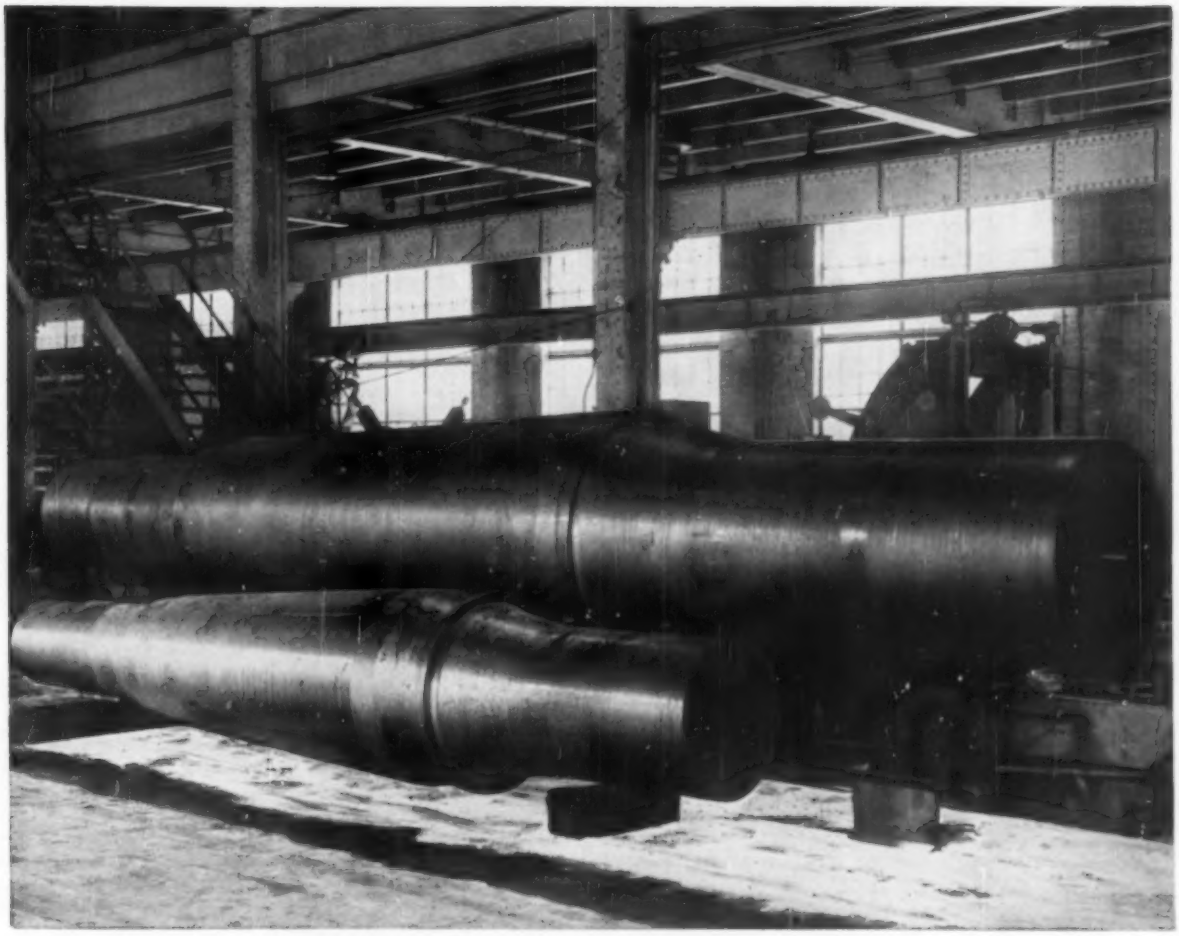
Another batch of liquor is pumped to the crystallization tank every two days and the regenerated liquor from the holding tank is run into the pickling tank. The crystals of copperas remaining in the crystallization tank are removed by scraping them from the sides and shoveling into 55-gal. drums. Some 500 lb. of the crystals are removed from each crystallization batch (about 1200 lb. per week). The drums of copperas are hauled to a dump for disposal.

In more than two years of operation, the process has proved to be an economical method for pickle liquor disposal. The major operating cost is removing crystals from the tank by hand labor. This could be eliminated by using a continuous crystallizer through which a slow stream of the pickle liquor would be pumped. The crystallizer could be provided with a cooling jacket and scraper blades for removing the crystals from the cooling surface and for discharging them to containers for disposal.

Analytical Control

A simple method of analysis was developed for a periodic check of ferrous sulphate and sulphuric acid in the pickle liquor. A 5-ml. sample of the liquor is titrated with 0.5 *N* sodium hydroxide using a pH meter. When the pH reaches 4.8, all sulphuric acid has been neutralized and the sodium hydroxide used is noted. The titration is continued to a pH of 9.5 at which point all ferrous sulphate has been titrated. The sulphuric acid and ferrous sulphate concentrations in vol.% are read from graphs. An inexperienced plant operator can carry out this analysis after a minimum of instruction.

If the copperas is to be sold for water treatment, it should be acid-free and consist of small free-flowing crystals. Markets for copperas are limited and there is probably no profitable outlet for the limited amounts from small pickling installations. Disposal of copperas on dumps to be earth covered should present no problem. Care should be taken to avoid dumping crystals on ground closely underlain by limestone or rock structures having solution cavities or fissures which would permit surface waters to carry the ferrous sulphate into the ground water. A clay soil prevents such movement. Even if some sulphate is dissolved, it will readily combine with calcium of the soil or rocks to form insoluble calcium sulphate.



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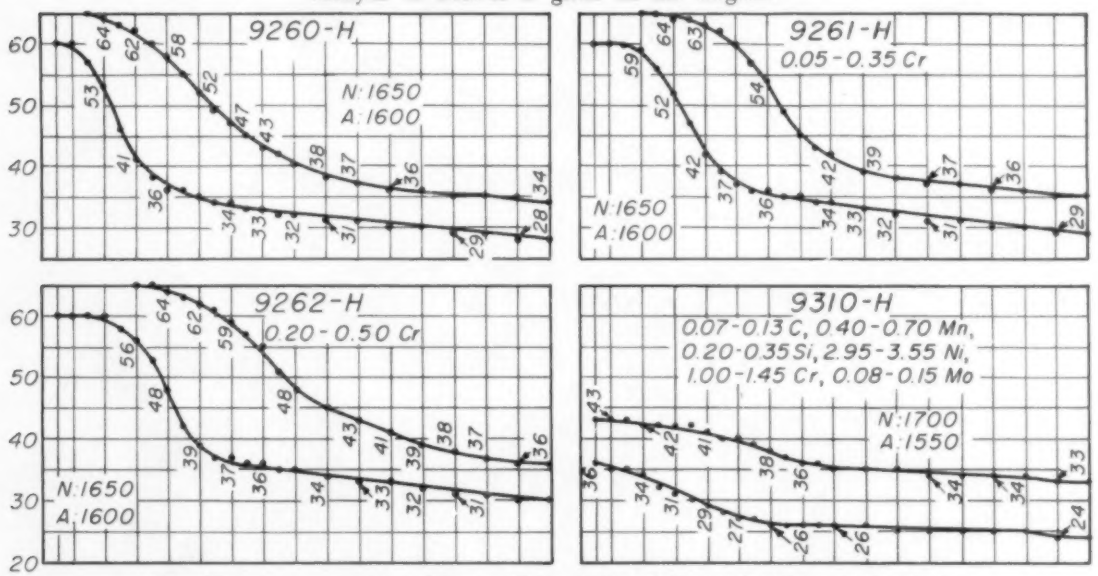
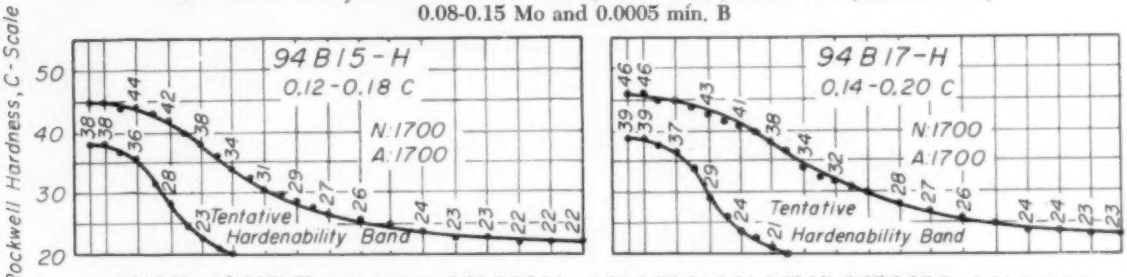
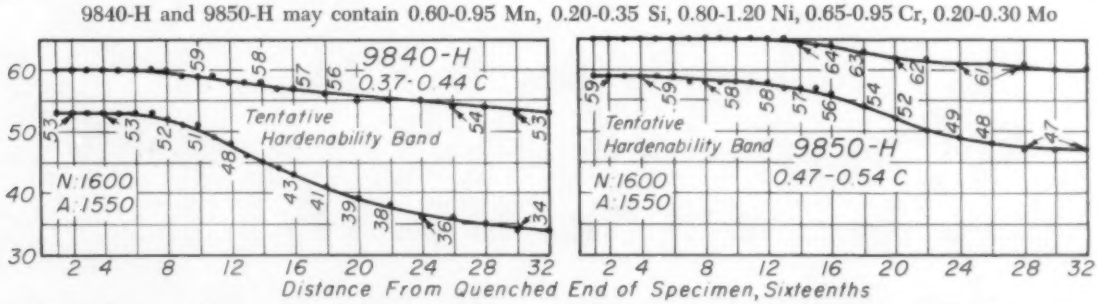


94 Bxx-H steels may contain 0.70 to 1.05 Mn, 0.20-0.35 Si, 0.25-0.65 Ni, 0.25-0.55 Cr, 0.08-0.15 Mo and 0.0005 mín. B



9840-H and 9850-H may contain 0.60-0.95 Mn, 0.20-0.35 Si, 0.80-1.20 Ni, 0.65-0.95 Cr, 0.20-0.30 Mo



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0.7	1.2	1.6	2.0	2.4	2.8	3.2	3.6	3.9	CENTER	QUENCH
0.8	1.8	2.5	3.0	3.4	3.8				SURFACE	MILD
0.5	1.0	1.6	2.0	2.4	2.8	3.2	3.6	4.0	3/4 RADIUS FROM CENTER	OIL
0.2	0.6	1.0	1.4	1.7	2.0	2.4	2.8	3.1	CENTER	QUENCH
2	4	6	8	10	12	14	16	18	Distance From Quenched End of Test Piece	

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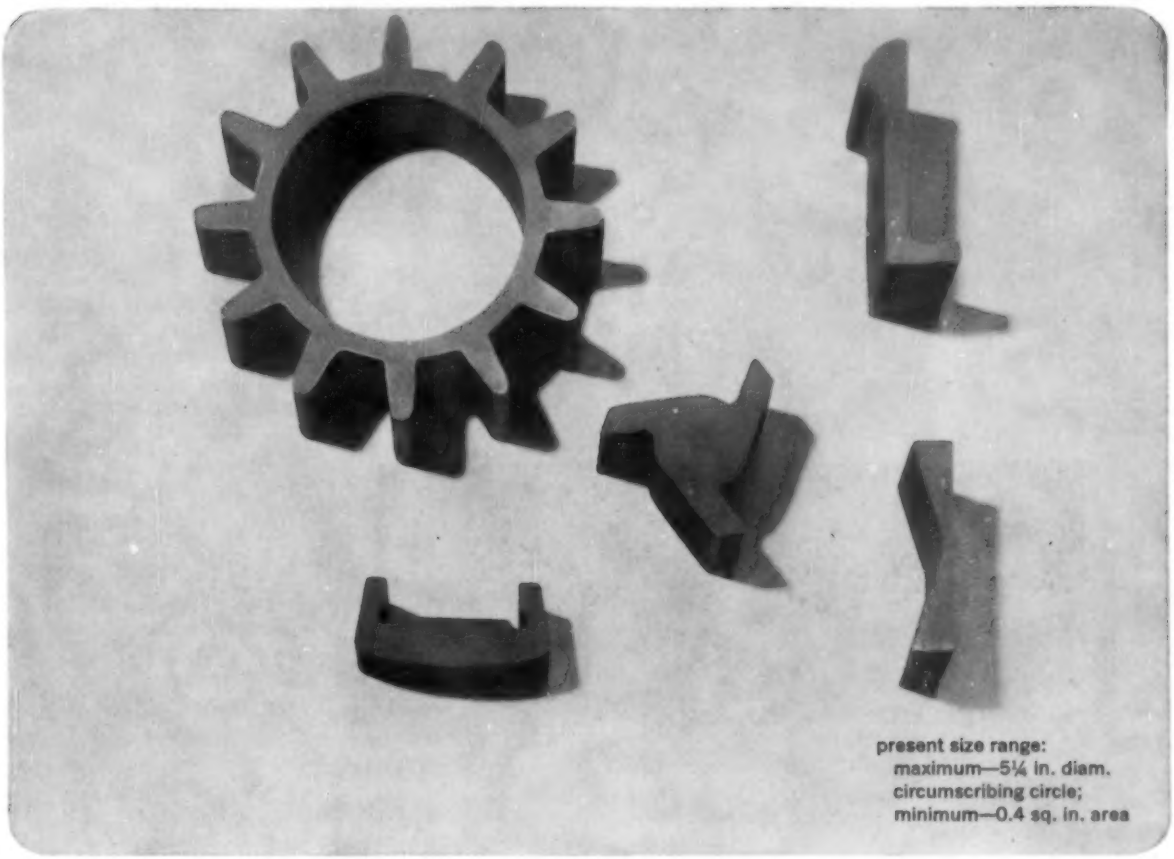

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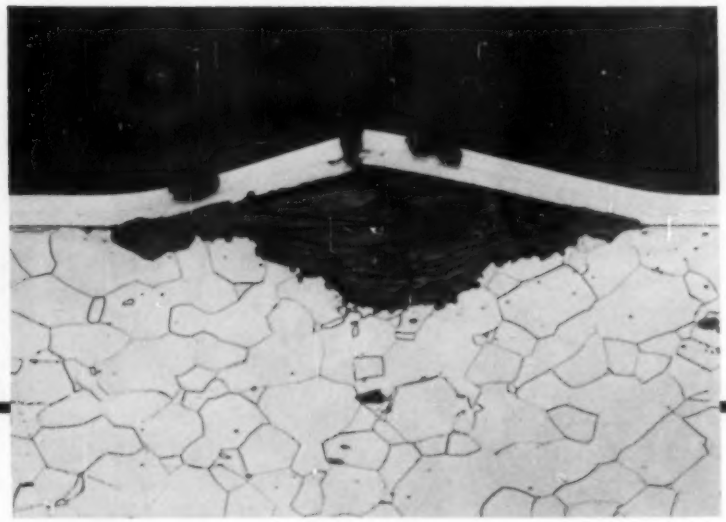

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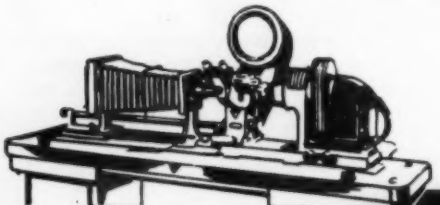

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Better Ways to Fabricate High-Temperature Materials

STAFF REPORT

Aircraft and missile needs are setting the pace for development of improved high-temperature materials and better methods for fabricating them. Investment casting in vacuum opens up a promising area. Slip casting can be used to fabricate parts that cannot be made any other way. Better control of processing variables in wrought fabrication gives improved properties. (A-general, Q-general, 2-62; SGA-h)

POWER PLANTS for aircraft and missiles generate some of the most stringent requirements facing materials engineers today. The critical range is above 1500° F. and may even extend to 5000° F. Although the temperature in jet engine blades is below 2000° F., high stresses, long operating periods and critical dimensions make this application difficult to satisfy. As engine temperatures go up, it is necessary to use stronger alloys all along the line.

But before any high-temperature material can be considered for use in engine components, it must lend itself to fabrication. This statement sets the stage for a Symposium held at the national meeting of the Metallurgical Society, A.I.M.E., in New York to discuss the effect of processing variables and fabrication practice on properties of high-temperature materials.

Where Do We Stand?

Today, engine builders are looking for a bucket alloy which will give a stress-rupture strength of 20,000 psi. at 1800° F. for 100 hr., reported F. S. Badger, vice-president, Haynes Stellite Co., a division of Union Carbide Corp.

A series of development alloys are reaching for this high figure by trying to balance high tungsten or high aluminum and titanium contents against the minimum acceptable ductility. These are all casting alloys. The nickel-base ones will stand a little more than 18,000 psi. under the desired conditions; the cobalt alloys are somewhat weaker. Alloys in these two groups are: Udimet-500 vacuum remelted, WI-52, Haynes Development Alloy (H.D.A.) 8294, Inco 713 and H.D.A. 8151. The Larson-Miller diagrams for these new alloys in the region of interest are shown in Fig. 1.

As the ultimate in high-temperature properties for these alloys is approached, close control of composition is essential. There is hope that minor element additions may be found to further enhance their properties. However, says Mr. Badger: "It will be surprising if the useful operating temperature range of nickel and cobalt-base alloys is developed more than another 100° F., particularly since oxidation resistance at surface grain boundaries is an ever-present problem with nickel-base, high-titanium and aluminum alloys." Thus prospects are poor for extending them beyond 1850 to 1900° F. — with designers crying for bucket temperatures of 2000° F. and up.

Where Do We Go?

A radically different approach is necessary to supply alloys to meet this higher temperature range for gas turbines, according to Mr. Badger. Also, the requirements of ramjets, high-speed aircraft, and missiles during re-entry raise the temperature demands on materials above the melting points of many metallic alloys. So we have an entirely new measuring stick for the super high-temperature materials needed for the future. Work is being concentrated on high-melting-point, reactive, refractory metals — tungsten, tantalum, columbium and molybdenum and their alloys. These metals, because they are both refractory and reactive, are particularly difficult to fabricate.

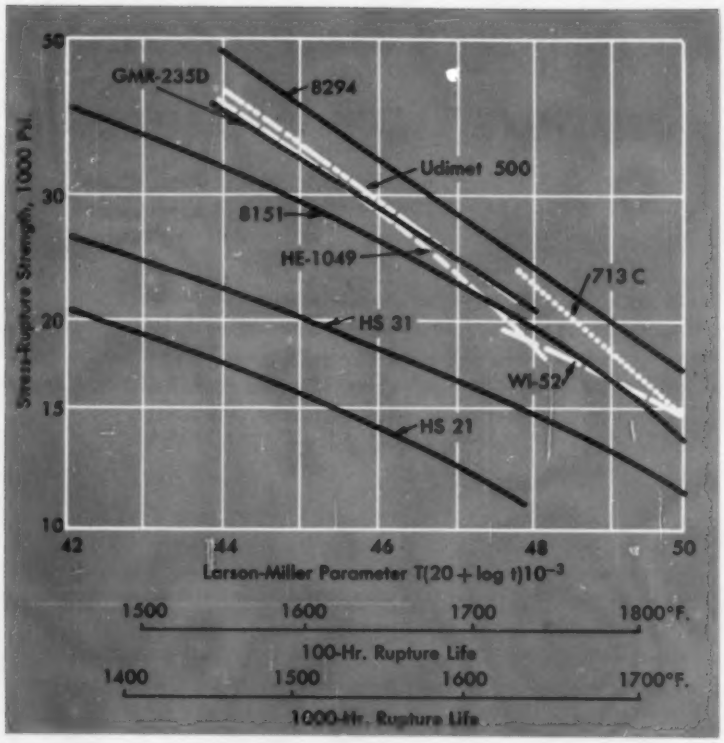


Fig. 1 — Comparison of Some of Today's Superalloys on a Larson-Miller Diagram

In one significant respect these superalloys are inferior to the old alloys: oxidation resistance. In the temperature range of 2000 to 2400° F., the oxidation resistance of the old alloys is generally inadequate for long service, but the new reactive metal alloys are very poor. It is proving more difficult to develop oxidation resistance than high strength in these high temperature ranges. Except for very short periods of exposure, it appears that metal cladding or a refractory coating will be required to protect against oxidation. This adds to their weight and makes high surface finish more difficult.

These difficulties point toward new types of high-temperature materials such as ceramics, metal-ceramics and high-temperature compounds fabricated by powder techniques.

Vacuum investment casting was one of the most promising new areas discussed at the Symposium. It appears that each alloy must be thought of individually, when the effects of vacuum melting and vacuum casting on mechanical properties are considered, according to John A. Miller of the Haynes Stellite Co.

The best procedure, from the standpoint of both quality and economics, is to use a vacuum melted alloy as the base stock. It may be remelted either in a vacuum casting furnace or in a controlled-atmosphere casting furnace. Investment molds are used with either of these furnaces to give precision castings. Both methods of casting are based on the premise that the properties of the vacuum melted alloy are developing in the master alloy. During remelting and casting, the alloy is protected to preserve these properties. Dissolved gases are maintained at a low level in the alloy and the

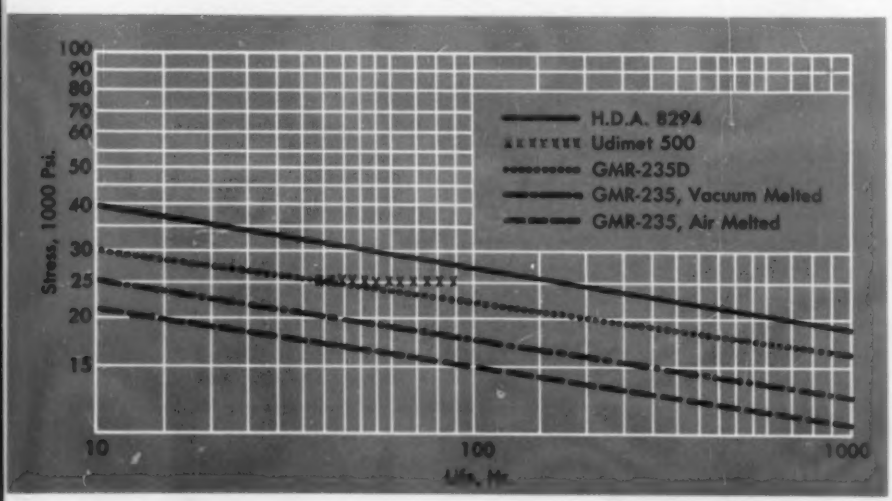


Fig. 2 — Stress-Rupture Curves for Vacuum Melted, Vacuum Investment Cast Alloys at 1700° F.

formation of nitrides and carbo-nitrides is largely eliminated. Figure 2 gives stress-rupture curves for vacuum melted investment cast alloys at 1700° F.

There are other advantages of vacuum casting. The investment mold is thoroughly degassed before casting. The elimination of back pressure from gas trapped in the mold by the entering alloy allows castings of thin cross section to be poured at temperatures considerably lower than would normally be possible with gravity pouring in air. The alloy appears bright and clear in the casting furnace during remelting. Freedom from oxide scum on the surface allows closer control of pouring temperatures.

The low, closely controlled temperature possible in vacuum casting gives finer-grained castings from nickel-base alloys. Turbine blades, which are about 5 in. in length with maximum thickness of about ⅜ in. in the base, are being produced in commercial quantities with maximum grain size of less than 1/16-in. diameter in all sections. Generally, the grain size is smaller than this in the airfoil section of the blade.

The grain size in the airfoil of a Udimet-500 alloy blade ranged from A.S.T.M. No. 4 to No. 1 with some grains as large as 1/32 in. in diameter in the thicker portion of the airfoil. It would not be uncommon to have grains ½ or ¾ in. in diameter in a blade of this size cast by usual methods. Mr. Miller said that the small uniform grain size obtained in these blades would give improved fatigue properties and better response to heat treatment.

GMR 235 is a nickel-base material, low in strategic alloy content, developed by the General Motors Research Div., Detroit. GMR 235 D is a slight modification of this alloy designed specifically for vacuum processing. It has higher hot strength as shown by the data in Fig. 3 brought out at the symposium by P. E. Hamilton, assistant chief metallurgist of General Motor's Allison Division.

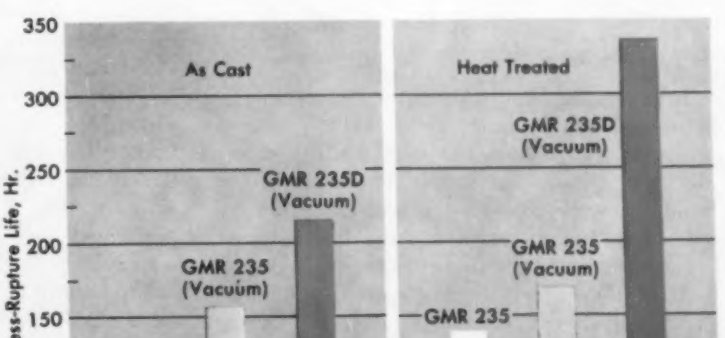


Fig. 3. – Average Stress-Rupture Life of GMR 235 Compared With Newer GMR 235 D Alloys at 1600° F. and 28,000 Psi.

Allison is using an aluminum dip on high-temperature parts (Aldip process developed by General Motors Research Div.) to improve oxidation and corrosion resistance and give better thermal fatigue properties. Parts are given a diffusion heat treatment after dipping. Stress-rupture properties are improved in the casting by heat treatment, as shown by Fig. 3. For example, the stress-rupture life of alloy GMR 235 D is increased by 125 hr. at 1600° F. under 28,000 psi.

Thermal fatigue is another property which is very much in the picture. Mr. Hamilton presented details of the machine designed at Allison to test thermal fatigue properties. A turbine blade is held by its foot in a vise. A gas-oxygen flame impinges on the leading edge. When a predetermined temperature is reached, the flame moves away and the blade is blasted by air to cool it rapidly. Thus, the blade is subjected to a cycle of thermal shocking. The current program of testing is 300 cycles at 2000° F., 100 cycles at 2050° F. and 100 cycles at 2100° F., unless failure occurs before the schedule is completed. It takes 15 to 23 sec. for heat-up (depending on temperature) and about 8 sec. to cool to 600° F. Failure by cracking is determined by frequent visual or fluorescent penetrant inspection of the blade edge.

Such test results gave added evidence of the value of vacuum investment casting. They showed that GMR 235 D alloy blades, Aldip treated and diffusion heat treated, gave 70% survival when the vacuum melted alloy was conventionally cast. When the alloy was

Fig. 4 – A Collection of Miscellaneous Parts Made by Slip Casting. The process may be used for fabricating such diverse high-temperature materials as silicon nitride, molybdenum disilicide, tungsten, tungsten carbide and metal-ceramic mixtures such as chromium-aluminum oxide and tungsten-chromium-aluminum oxide

vacuum cast, the survival was 100%. However, vacuum cast parts cost more, so economic considerations come into the picture too.

The slip casting process for making shapes consists of dispersing finely divided materials in a suspending medium, casting the resultant stable suspensions into absorbent molds and then sintering to increase density and strength. The primary advantage of the slip casting process, according to L. M. Schifferli, Jr., Haynes Stellite Co., who discussed this fabrication method at the Symposium, is that it makes it possible to produce parts economically from many high-temperature materials which could not be processed by any other method. Figure 4 shows a variety of parts which have been made by the process. Three high-temperature materials were used. Their composition is:

	Weight Per Cent		
Material	LT-1	LT-1B	LT-2
Chromium	77	59	25
Molybdenum	–	20	–
Tungsten	–	–	60
Aluminum oxide	23	19	15
Titanium oxide	–	2	–

In operating the slip casting process, slip is poured into a plaster mold cavity. After a sufficient wall section has built up, the excess slip may be drained simply by inverting the mold. A well-prepared slip will allow the resultant casting to shrink slightly; this helps in removal of the shape from the mold.

After it has dried, the shape must be sintered to develop its full value as an engineering material. Sintering is a rather complex physical-chemical phenomenon which causes significant bonding between grains with elimination of substantially all porosity. Solid state sintering is done at temperatures considerably below the melting point of the materials in the slip.

Plaster of paris is the most commonly used mold material. Slips are complex colloidal suspensions; their properties are determined by powder characteristics (size and particle distribution), by the characteristics of the liquid used as the suspending medium and also by the properties of a third additive called a dispersing or deflocculating agent.

Strength at elevated temperatures is outstanding. They retain appreciable strength at temperatures considerably above the maximum usable temperature for ordinary high-temperature alloys. Sintering temperature is generally in the range 2850 to 3100° F. Sometimes parts are used at temperatures in excess of that at which they were sintered. However, impact resistance is low; they have essentially no ductility. Typical properties of sintered metal-ceramics are given in Table I.

The thermal expansion of sintered metal-ceramics is lower than most metals and this contributes to good thermal shock resistance. Densities are quite high for sintered materials. Oxidation resistance is outstanding, especially for compositions with high chromium content (LT-1 and LT-1 B). Oxidation loss at 2200° F. for 100 hr. compares favorably with the best nickel-base alloys and is superior to the refractory metals. The tungsten composition (LT-2) has rather poor oxidation resistance; in spite of this, however, this composition has performed well as a rocket nozzle when used with solid propellents.

Slip casting as a method for fabricating parts from silicon nitride is well developed. Molybdenum disilicide and tungsten carbide, both with and without metallic binder, are being cast into parts. Slip casting of refractory metals such as tungsten and molybdenum is being evaluated.

Wrought Alloys – Data presented by D. W. Schulz, Haynes Stellite Co., on nickel and cobalt-base alloys indicate that mechanical properties

Table I – Typical Properties of Sintered Metal-Ceramics

Property	Units	LT-1	LT-1 B	LT-2
Modulus of elasticity	psi. at 70° F.	36×10^6	38×10^6	38×10^6
Modulus of elasticity	psi. at 1800° F.	33×10^6	31×10^6	33×10^6
Transverse strength	psi. at 70° F.	45,000	55,000	73,000
Transverse strength	psi. at 1800° F.	26,500	54,000	—
Transverse strength	psi. at 2100° F.	16,600	29,000	—
Transverse strength	psi. at 2400° F.	6,700	11,800	—
Compressive strength	psi. at 70° F.	110,000	240,000	—
Sintering temperature	—	2850° F.	2900° F.	3100° F.
Hardness	Rockwell C-scale	37	50	52
Thermal expansion	in./in./°F.	4.7×10^{-6}	5.2×10^{-6}	4.6×10^{-6}
Oxidation resistance at 2200° F., 100 hr.	continuous, in. per yr.	0.105	0.095	37.5
	intermittent, in. per yr.	0.131	0.159	231.0
Maximum service temperature	—	2400° F.* 3000° F.†	2800° F.	3100° F.‡

*Continuous service †Short-time service ‡Reducing atmosphere

can be increased significantly by cold working. He predicted that possibilities here have not been fully developed and that prospects of obtaining even higher mechanical properties are good.

Cold working by pressing, drawing, rolling and associated processes will increase the ultimate tensile strength, yield strength and rupture lives (below the recrystallization temperature) of these alloys. These improvements are generally realized at some sacrifice of elongation and reduction of area. Another point brought out by Mr. Schulz: By properly heat treating cold reduced alloys, room and elevated-temperature properties can be increased beyond values for cold reduced material alone.

Cold reduced and cold reduced and aged high-temperature alloys are in increasing demand for such applications as bearings in high-temperature applications, springs, structural members and other uses where good mechanical properties must be maintained under extremely adverse operating conditions.

Udimet-500 – G. J. Guarnieri and E. J. Vargo, Thompson Products, Inc., told the Symposium that to achieve the high-temperature strength of this alloy in a forged turbine bucket requires considerable control of processing and heat treating variables. Present-day practices used throughout industry for manufacture of Udimet-500 buckets result in some compromise of strength for ductility (or vice versa) in order to get maximum properties in the finished part. They presented data to show that ductility in this alloy is primarily dependent on mode of occurrence of the $Ni_3(Al, Ti)$ precipitate while the rupture strength at 1650° F. is mainly controlled by grain size. Since these two microstructural features may be controlled independently, it should be feasible to develop processing methods capable of giving maximum stress-rupture strength together with adequate ductility in the fabricated bucket.

Thompson has investigated several metallurgical variables subject to control in processing of Udimet-500 turbine buckets with respect to ductility and effect on stress-rupture strength at 1650° F. Some of the conclusions are:

1. Increasingly higher solution temperatures in the range of 1900 to 2250° F. increase stress-rupture life due to the combined effect of grain coarsening and increased solution of the α' [$Ni_3(Al, Ti)$] phase.

2. Solution temperatures below 1975° F. develop inferior stress-rupture properties because of the incomplete solution of the α' phase and also (to a lesser extent) because of the high degree of spheroidization of the residual α' constituent.

3. Stress-rupture life at 1650° F. is relatively insensitive to cooling rate from the solution temperature. However, with slower cooling rates, there is a trend toward shorter stress-rupture life as a result of the α' agglomeration.

4. Residual cold work remaining in fabricated Udimet-500 will materially reduce its stress-rupture life at 1650° F. due to the instability of the microstructure.

5. Maximum rupture strengths at 1650° F. are generated by working procedures which retain an equivalent cold worked condition of the order of 5% followed by reheating at temperatures of 1975° F. and above to cause grain growth and proper solution of the α' phase.

Pearlitic Malleable Iron—

an Industry Report

*By JAMES H. LANSING**

The rapid increase in use of pearlitic malleable castings in recent years presages many new areas of application for the future. (A-general, 17-57; CI-s)

THE CHART on the opposite page, depicting the growth of pearlitic malleable castings, speaks for the many new applications this material has found over the past few years. Because these castings are readily machinable, have excellent resistance to wear, are shock resistant and are easily selectively hardened, they are replacing steel forgings and parts formerly machined from bar stock in a variety of applications.

They have the inherent advantages of castings: Interiors may be cored out as required and metal may be placed in the required locations in light or heavy sections, or both. The metal is free from centerline shrinkage, gas holes, segregation, and, with a uniform structure, has uniform strength in all directions. Indicative of the broad range of properties obtainable in pearlitic malleable irons are the specifications of the American Society for Testing Materials; Specification A 220-55 T provides the values given in Table I.

Pearlitic malleable differs from standard malleable in that it contains a controlled amount of combined carbon, accounting for its higher hardness, strength, and wear resistance. Standard malleable, on the other hand, is used where good strength, toughness and outstanding machinability are needed but where the higher strength, hardness and wear resistance of pearlitic malleable are not essential. For example, in automotive applications, steering gear housings are made of standard malleable, but automatic transmission parts are made of pearlitic malleable.

True for pearlitic malleable, as for standard malleable iron, is the fact that the test bars which are used as a measure of the properties of the material are not pieces machined from heavy, specially cast and fed blocks. On the contrary, they are a regular lot of pearlitic malleable castings, normally gated and fed, and tested in the same dimensions in which they are cast. With bar sections ranging from ⅝ to ¾ in., they are truly representative of the normal ¼ to 1½-in. sections in which pearlitic malleables are most widely produced and used.

Pearlitic malleable castings are used in a wide variety of applications. Grades 45007, 48004, 53004, 60003 and 80002 are used widely in the automotive industry as adapted by considerations of both production and use. Figure 1 shows a number of other applications including gun frames, gear housings, reamers, swivel parts, ratchets, pintles, shifter forks, gear blanks, and cutter frames, made to the 45010 and 50007 specifications. Other uses include bearing wedges for freight car roller bearings, farm implement suspension arms, frame side rails and gears,

*Technical and Research Director, Malleable Founders' Society, Cleveland.

Table I — Properties of A.S.T.M. Pearlitic Malleable Iron Castings

GRADE	TENSILE STRENGTH, MIN.	YIELD STRENGTH, MIN.	ELONGATION IN 2 IN., MIN.
45010	65,000 psi.	45,000 psi.	10%
45007	68,000	45,000	7
48004	70,000	48,000	4
50007	75,000	50,000	7
53004	80,000	53,000	4
60003	80,000	60,000	3
80002	100,000	80,000	2

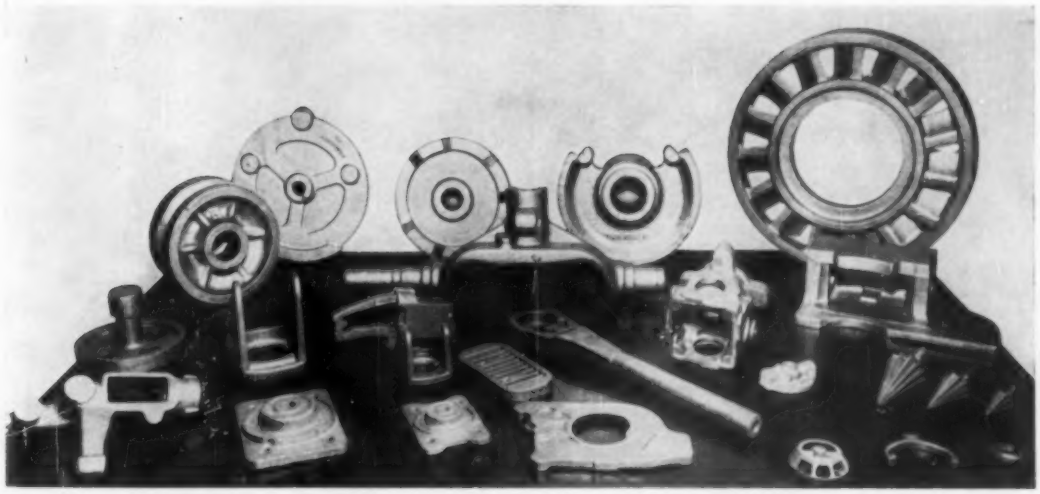


Fig. 1 – Typical Castings of Pearlitic Malleable Iron for General Application (Courtesy Eastern Malleable Iron Co.)

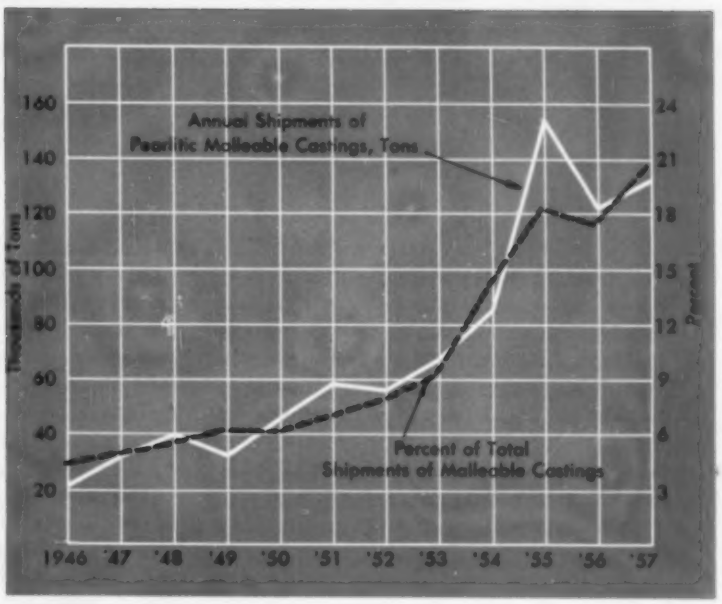


Fig. 2 – In the Last Decade There Has Been a Remarkable Increase in the Use of Pearlitic Malleable Iron Castings as Shown by the Tonnage Figures Reported by Members of the Malleable Founders' Society

large nuts for tractor drive shafts, and chain and conveyer equipment parts. Pearlitic malleables are particularly adapted to localized hardening. By either flame or induction heating, they are readily hardened to Rockwell C-50 to 55.

Pearlitic malleable is not a new material but rather a time-tried one which has long demonstrated its usefulness and dependability. In 1919, Enrique Touceda, professor of metallurgy at Rensselaer Polytechnic Institute, described it at a meeting of the American Society of Mechanical Engineers, quoting tensile strength values of 80,000 psi. with 5% elongation. It is in the last decade, however, that greatest use has been made of the material. As will be seen from the chart in Fig. 2, its use increased more than 200% in this period. The user or prospective user today will find fifty or more malleable iron foundries (well distributed geographically) ready to supply pearlitic malleable castings.

The article on the following pages by Carl F. Joseph tells about progress being made in using pearlitic malleable for automotive parts. Other manufacturers can also make greater use of the outstanding properties of this material.

More on Pearlitic Malleable

Castings for Tougher Jobs

*By CARL F. JOSEPH**

Pearlitic malleable iron is opening up new horizons for cast parts in automotive and other applications. A new grade of higher hardness has been developed for parts requiring good wear resistance and toughness in the as-machined state. Machinable castings, with even higher hardness – up to Brinell 400 – are in the future picture. (Q-general, E11, 17-27; CI-s)

CASTABLE FERROUS ALLOYS are used extensively today to make automotive parts. Because of their ability to assume the shape of practically any molded cavity, they allow greater freedom in design. They also possess certain inherent physical characteristics not present in the forgeable alloys.

This is particularly the case with ArmaSteel, a closely controlled pearlitic malleable iron produced by Central Foundry Div., General Motors Corp. The presence of temper carbon particles in a steel matrix contributes to these desirable properties: (*a*) high resistance to mechanical wear, (*b*) excellent damping qualities, (*c*) superior machinability, (*d*) good selective hardening, (*e*) high yield strength ratio, and (*f*) excellent finishing properties.

Production Control

The production of ArmaSteel starts with accurate control of all raw materials going into the melting process. The history of ferro-alloys, pig iron, steel, refractories and coke is carefully studied. Quality of raw materials plays an important role in making a good casting. Sometimes this is not too clearly appreciated by foundrymen. The methods used in melting the iron are not as important as the control of the process. There are numerous melting methods for pearlitic malleable iron – all producing quality castings. Chemical analysis and metallurgical controls are common practice in modern foundries today.

Chromium Control

The most vicious element the metallurgist in the malleable foundry has to contend with is chromium. Small amounts are detrimental to the structure and physical properties of the iron. Most malleable iron producers must keep chromium under 0.03% and prefer 0.01 to 0.02%. The increasing use of steel scrap in the charge makes it a problem, at times, to keep the chromium under 0.03%. For example, some stainless scrap may accidentally find its way into a baled sheet bundle, or high-chromium bar stock may get into structural steel scrap. This could easily bring the chromium up to 0.10% which is too high for most malleable iron producers.

A satisfactory way to counteract chromium is by the use of boron in amounts of 0.001 to 0.004%. Boron allows a higher percentage of

*Technical Director, Central Foundry Div., General Motors Corp., Saginaw, Mich.

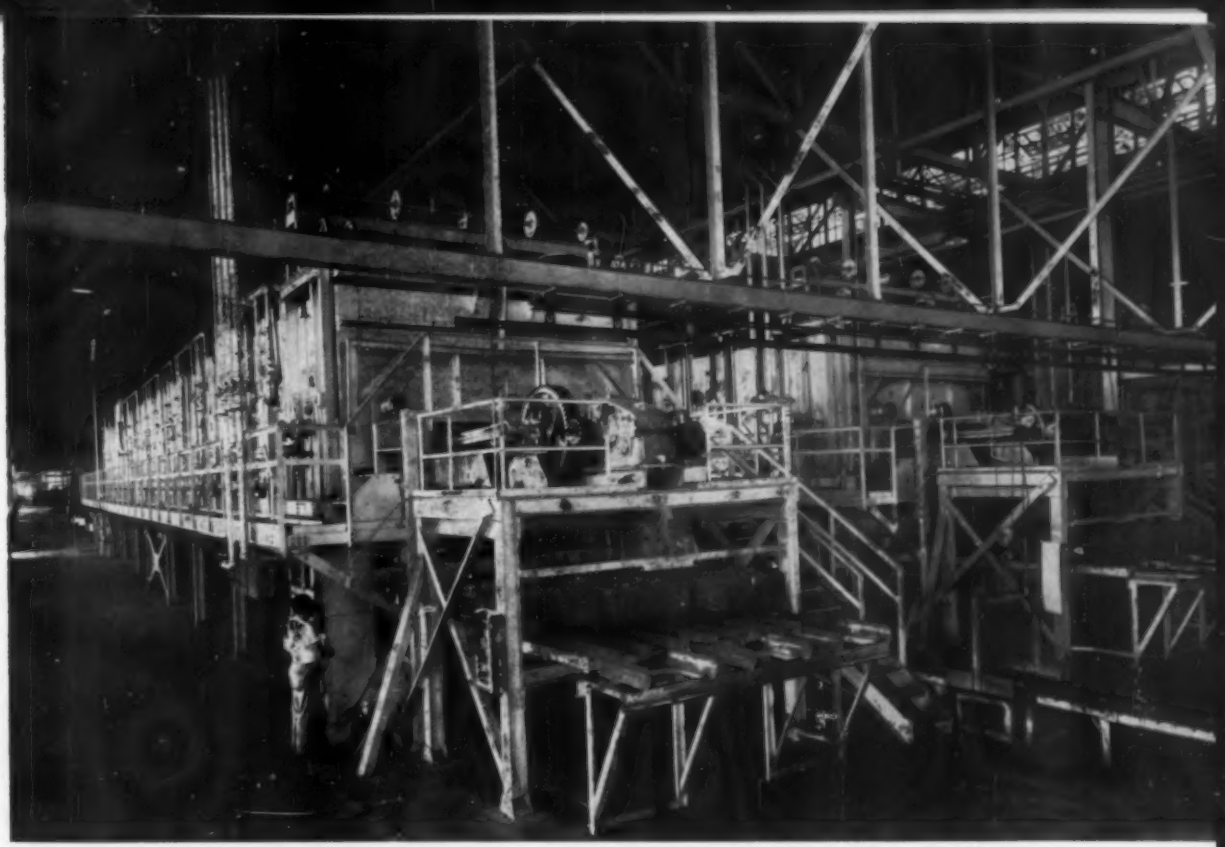


Fig. 1 – Heat Treatment of Pearlitic Malleable Iron Castings Is Done in a Controlled-Atmosphere, Radiant Tube Furnace at Central Foundry Div., General Motors Corp.

chromium in the iron without detrimental effect. It also speeds up the annealing cycle in heat treating the white iron casting. At Central Foundry we have reduced our annealing time by one third by using about 0.003% B. Boron is added to our cupola charge in 50% ferrosilicon alloy, purchased containing 0.050 to 0.060% B. Additional boron can be added to the molten iron using ferroboron, if needed. Boron also produces much smaller temper carbon spots, which aids materially in machinability, without appreciably affecting physical properties of the metal.

Some heavy parts are difficult to cast without getting primary graphite. This must be avoided. The addition of small amounts of bismuth (U.S. Patent 2,370,225, to General Motors Corp.) prevents the formation of primary graphite in castings 2 in. or larger in cross section. We use 0.005% Bi on medium-size castings, up to 0.02% on large castings. It improves the physical properties without any adverse effect on the annealing cycle.

Heat Treatment

Heat treatment of our pearlitic malleable iron is done in atmosphere-controlled, radiant tube furnaces such as shown in Fig. 1. They are 120 ft. long by 18 ft. wide and are as gas tight as possible. Neutralene gas is used to maintain a high-nitrogen atmosphere. The atmosphere in the furnace contains no free oxygen, has up to 15% carbon monoxide, less than 1% carbon dioxide (normally 0.5%), and the balance is nitrogen. This type atmosphere allows the temper carbon spots to come close to the surface of the casting which improves the machining characteristics of the metal. Maintaining the proper atmosphere in the furnace in annealing pearlitic malleable iron is the key to improved machinability.

Heat treatment is conducted in two steps: The first operation is a malleablizing treatment of the white iron casting. This is conducted at 1700 to 1750° F. for 10 hr. or more, depending on the composition of the iron. The high temperature breaks down the massive iron carbide (cementite). This treatment is followed by rapid air quenching from about 1600° F. Castings are dumped and spread out on a metal screen and air is blown through them to give a uniform, fast air quench.

The second step is to temper the castings to a uniform Brinell hardness, which is done by heating for about 4 hr. at the temperature needed to

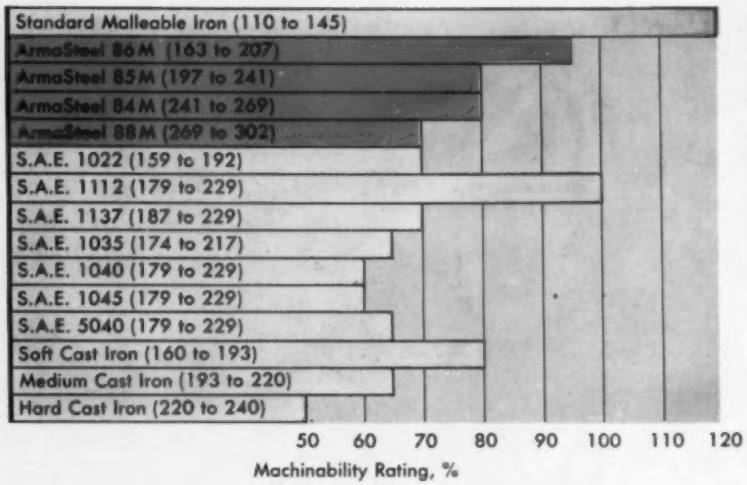

Standard Malleable Iron (110 to 145)
ArmaSteel 86M (163 to 207)
ArmaSteel 85M (197 to 241)
ArmaSteel 84M (241 to 269)
ArmaSteel 88M (269 to 302)
S.A.E. 1022 (159 to 192)
S.A.E. 1112 (179 to 229)
S.A.E. 1137 (187 to 229)
S.A.E. 1035 (174 to 217)
S.A.E. 1040 (179 to 229)
S.A.E. 1045 (179 to 229)
S.A.E. 5040 (179 to 229)
Soft Cast Iron (160 to 193)
Medium Cast Iron (193 to 220)
Hard Cast Iron (220 to 240)
50 60 70 80 90 100 110 120
Machinability Rating, %

Fig. 2 – This Chart Compares the Machinability of Several Grades of Pearlitic Malleable (Solid Color Bars) With Other Cast Irons and Forging Steels. Comparison basis: S.A.E. 1112 (bessemer screw stock) equals 100%. Numbers in parentheses are Brinell hardness ranges for the materials

meet the hardness specification. This will vary from 1250° F. for Brinell 197 to 241 up to 1330° F. for Brinell 163 to 207.

The use of oil quenched and tempered pearlitic malleable iron is increasing due to better uniformity of castings, higher physical properties and improved machinability. This class of castings is produced by taking the iron from the first step in the heat treating cycle, reheating to 1550 to 1600° F., holding at this temperature for 20 to 30 min., then quenching in oil. This gives a hard, brittle casting with hardness above Rockwell C-50. The material is tempered to the Brinell hardness ranges of 269 to 302, 241 to 269, 197 to 241, or 197 to 229 – depending on the class being produced.

Mechanical Properties

Properties of pearlitic malleable iron differ according to the amount of combined carbon in the matrix. As the combined carbon increases, the casting becomes stronger, harder and less ductile. By controlling the amount of combined carbon, the mechanical properties can be varied over a wide range. Some of the most important characteristics are detailed below:

1. **Machinability** – In general, the machinability of pearlitic malleable iron is 10 to 30% better than steel forgings of the same hardness. Figure 2 compares the machinability rating of cast iron and various types of steel forgings with pearlitic malleable iron. The comparison is based on S.A.E. 1112 (bessemer screw stock) at 100%. In establishing these ratings, the cutting speed of S.A.E. 1112 is at the rate generally used in turning it on automatic screw machines. The rate of feed is altered to that necessary to give normal tool life and good surface finish when using a coolant. When other metals are tested, the feeds and speeds are varied from these basic rates to whatever rate is necessary to get a comparable surface finish. The ratio of these rates and speeds and feeds for each metal determines the per cent machinability.

Fig. 3 – This Automotive Rocker Arm Cast From Pearlitic Malleable Iron Operates on a Hardened Steel Shaft Without a Bronze Brushing

2. **Damping Characteristics** – This property is valuable in motors using a cast crankshaft where quiet operation is a factor. A typical shell molded automotive crankshaft weighs 64 lb.; finished machined it weighs 54 lb. – or 10 lb. of metal removed in machining as against 14 lb. for an equivalent forged crankshaft.

3. **Bearing Properties** – In the automotive rocker arm (Fig. 3), operating on a hardened

Table I – Properties and Applications of Various Types of Pearlitic Malleable Now Produced at Central Foundry

ArmaSteel Grade	Tensile Strength	Yield Strength	Elongation in 2 in.	Brinell Hardness	Impression 3000 kg.	Applications
GM86M	70,000 psi.	48,000 psi.	5.0%	163-207	4.2-4.7 mm.	For less highly stressed parts, such as C-clamps, auto front wheel hubs, diesel engine brackets, levers, transmission cases.
GM85M	80,000	60,000	3.0	197-241	3.9-4.3	For moderate strength parts. Used for diesel pistons, differential axle cases, rocker arms, and transmission clutch hubs.
GM84M	100,000	80,000	2.0	241-269	3.7-3.9	For high-strength applications, such as transmission gears and universal joints. Parts are oil quenched and tempered at foundry.
GM88M	105,000	85,000	2.0	269-302	3.5-3.7	Strength characteristics similar to alloy steel forgings. Good wear resistance and high yield strength in as-machined state. Used for universal joint yoke, idle and balancer gears, planet gear carrier.

Fig. 4 – Pearlitic Malleable Iron Is Used for This Diesel Engine Piston Which Is Given a Mirror-Like Finish

steel shaft, the bronze brushing can be eliminated. This illustrates the excellent nonseizing properties of metal-to-metal wear.

4. **Fine Machine Finish** – Pearlitic malleable iron gives a mirror-like finish in parts requiring it, such as the diesel engine piston in Fig. 4.

5. **High Yield Ratio** – With a minimum yield strength of 80,000 psi. and ultimate tensile strength of 100,000 psi., pearlitic malleable iron can be used for many highly stressed parts, such as the universal joint yoke in Fig. 5.

6. **Selective Hardening** – Pearlitic malleable iron responds readily to localized hardening either by flame or induction methods. Hardening is used on many parts, such as rocker arms, small crankshafts and gears.

7. **Fatigue Life** – Resistance to fatigue failure is good. The endurance limit of pearlitic malleable iron is 0.50 to 0.55 of the tensile strength. It is less sensitive to notches in fatigue than is steel – an important design consideration. The "K" ratio as compared with steel is about 1.5.

8. **Wear Resistance** – It withstands excessive wear under heavy loads at high speed. Castings are oil quenched to give a uniform structure of high strength, free from ferrite.

Classes of Material

Pearlitic malleable iron is produced in various classifications at Central Foundry to meet a broad range of applications, as shown in Table I. Parts which do not demand the highest mechanical properties can be made under specification GM 86 M with some gain in machinability because of the lower Brinell hardness. Representative castings are C-clamps, automobile front wheel hubs, many diesel engine brackets and levers, and some automatic transmission drums. GM 85 M is a medium-strength material which is used in applications such as diesel pistons, differential axle cases, rocker arms and transmission clutch hubs. Castings made from specification GM 84 M (high-strength material) are oil quenched and tempered at the foundry. They find uses in transmission gears and universal joint yokes.

Our newest pearlitic malleable iron, GM 88 M, was developed for parts requiring high strength and good wear resistance in the as-machined state. This new material is oil quenched and tempered to a Brinell hardness specification of 269 to 302. No further heat treating is required. It was developed to take advantage of recent advances in machines and cutting tools which make it possible to machine materials of higher hardness. The object of the development was a casting with increased wear resistance and high yield strength, yet retaining machinability.

Fig. 5 – High Strength of Pearlitic Malleable Iron Makes It Useful for Highly Stressed Parts Such as This Universal Joint Yoke

Fig. 6 – This Planet Gear Carrier for an Automatic Transmission Is Made From a New Class of Pearlitic Malleable Iron Having Tensile Strength of 105,000, Yield Strength of 85,000 and Brinell Hardness in the Range 269 to 302. It combines exceptional wear resistance with machinability in a cast part

GM 88 M grade is applicable to many parts. It is being used for an automatic transmission planet gear carrier (Fig. 6), formerly produced as an alloy steel forging. Idler and balancer gears on diesel engines were formerly made from carburized and hardened steel. GM 88 M is being used here with excellent results at considerable cost savings. It is also being used for castings for universal joint yokes where it has replaced steel forgings of Brinell 225 to 285.

Pearlitic malleable iron in a harder Brinell range (approaching 400) is being investigated for applications needing extremely good wear characteristics along with machinability. Castings with a Brinell range of 311 to 375 are now being produced for automotive parts.

Quality Control

There was a time when visual inspection was the only test to sort out defective castings. Now regular procedure on many castings calls for 100% inspection using Magnaflux or Magnaglo checking, sonic testing, or some other means of finding defective parts. Cobalt-60 radiography is used regularly to determine whether a casting is properly gated for production and also to check castings periodically during operation. With modern means of testing available, there is no reason for foundries to produce anything except sound, reliable castings.

Metallurgy in Industry— a Look Ahead

*By H. S. TURNER**

To devise the necessary new and cheaper operations, the process metallurgist must work with models and pilot plants (not miniatures of present equipment) and be guided by a thorough knowledge of reaction kinetics. Experimentation with existing full-scale equipment is certain to give results of only limited application and at high cost. (A9p, 17-56)

THERE IS SPECIAL PRESSURE on the steel industry to control operating costs and the capital requirements of new facilities. This pressure arises from the price-cost squeeze so painfully applied in the current period of reduced operation; it introduces serious financial obstacles to the industry's plans for the new plant inevitably required as our economy resumes its long-range expansion. Bankers and other investors exercise understandable reluctance to invest in new — but "more of the same" — facilities that will certainly show a lower net return than is produced by present partially depreciated steel plants.

This sounds like a problem for our friends in finance, production, and sales; and it is, but it is my interpretation that greatest leverage in this campaign can be exercised by the process metallurgist, and on this account larger proportions of our scientific and engineering efforts must be directed toward supporting his efforts.

However, there are several factors which handicap his effectiveness and restrict his freedom of choice in attacking these problems. First, I would like to point out the principal grindstone with which we must abrade his nose: He must achieve much of his success in controlling costs while relying on present equipment, in spite of the restrictions it imposes on his program.

We are employing devices that were conceived many years ago for a substantial share of the smelting and refining steps in use today. These are devices based on qualities, relative abundance and costs of raw materials that bear little resemblance to present circumstances and no resemblance at all to those of the future. They were created in a technology that is only a skeleton of our knowledge of today.

Nevertheless, we must achieve a substantial proportion of the desirable improvements in over-all cost and productivity with the equipment we now have. We just do not have the money to make any wholesale replacement of our conventional plants. We wouldn't have it even if new process concepts offered the incentives to do so.

To the outsider, this application of new technology to old equipment must seem like putting tubeless tires on a Model-T Ford. But the alternative is to buy a $15,000 late model Rolls Royce for the same basic transportation job: So we are just going to have to keep on polishing that Model-T.

So much for the factors which restrict freedom of choice. Now for some new tools which we must give to our process metallurgists. The first is greatly expanded data on applicable chemical kinetics. The second is an adequate understanding of the chemical engineering proportionality between pilot plant and tonnage equipment that would then open the way for the development of useful process improvements at lower cost. Let us look at each of them with some care.

Kinetics — To date, much of the improved understanding of our iron and steelmaking processes has come through thermodynamics and

*Vice-President, Research and Development, Jones & Laughlin Steel Corp., Pittsburgh. Portions of a paper presented at the Silver Anniversary celebration of Metals Research Laboratory, Carnegie Institute of Technology.

equilibrium studies. This is the natural result of taking up first things first and deferring the relatively more difficult job of dealing with rates and reaction mechanisms. Now, however, the tougher job must be given more emphasis.

The practical application of a knowledge of kinetics is especially well illustrated by two examples from the chemical field. In these examples, kinetic data were carefully used to thwart Nature by denying equilibrium controls the opportunity to take place. The result was to pluck out of the reaction system a highly desired product which would otherwise have been undesirably altered by reactions continuing to move toward equilibrium.

Exposure of the pentane hydrocarbon to chlorine had hitherto led to a profuse mixture of products containing one, two and more chlorine atoms scattered over the pentane molecule. The incentive for a controlled chlorination leading to a single substitution at a predetermined point lay in the prospects for making a low-cost intermediate useful in synthesizing plasticizers and other valuable organic chemical products. Equilibrium data for the reaction between pentanes and chlorine gave little encouragement. Nevertheless, such conditions were found. The system was starved, as far as chlorine is concerned, during a carefully calculated residence time under selected reaction conditions; then the gases were quenched and all reaction ceased. Therefore, despite the readier responses of the monochlorinated pentane to further chlorination, when compared with the original pentane, the desired monochloro product was produced and successfully extracted from the system. An entirely new approach for commercial development was opened.

A more recent example is in the production of acetylene from natural gas. It had been postulated that methylene radicals – and in all likelihood acetylene itself – could be an intermediate product in the complete oxidation of methane. However, it took some very careful studies of the kinetics and mechanism to take advantage of the transitory existence of the much-desired acetylene to make this valuable chemical product from a cheap raw material. As a consequence, at least two commercial processes have been evolved which provide for most carefully calculated residence times and reaction conditions that favor the formation of the desired product. Quenching prevents destruction of the desired product by the otherwise logical sequence of oxidation reactions.

There is nothing simple about this kind of work. And to put it in full perspective, a considerable increase in available data on the appropriate chemical kinetics would only supplement the other rate-limiting data needed by the process metallurgist. In a practical sense, attempts to juggle the operating procedures of existing facilities to take advantage of the data we now have soon reveal that the real limitation to increased production lies in some item of mundane equipment such as the speed of the skip hoist or the size of a charging box. However, my strong vote for more kinetic data remains on the record. University research, operating with those in industry responsible for the applications, provides an effective team for the job.

Beyond application to existing processes, this information stands as a prerequisite for the effective development of the new processes and equipment that are surely destined to become major factors in the expansion of the steel industry over the next 25 years. Here we can hope for entirely new concepts of process and equipment design. We may be seeing some of a "dream sequence" now in the publicity given to the "Cyclosteel" process of the British. I will not evaluate this other than to say that it represents an imaginative approach toward a low residence time, low-inventory reactor that could truly revolutionize our conventional concepts of basic metallurgical process equipment.

Pilot Plant – It would indeed be wonderful to be rich in resources of kinetic data, but to put them to work efficiently we need a second tool. This tool is a working understanding of the scale-up factors of our major processes that would permit effective and efficient investigations on a pilot-plant scale. This target is reached through the development of theory derived from the study of models. To the best of my knowledge, work along these lines in the steel industry aimed at predicting large-scale operations is very limited – for example, only at the Swinden Laboratories in England, at Monroeville Laboratories in the United States, and perhaps a few others.

I would like to quote from a text published in 1957 by Johnstone and Thring, "Pilot Plant Models and Scale-Up Methods":

"It is a well-known fact that small-scale experiments are not always a reliable guide to large-scale results. Sometimes a process which is satisfactory in the pilot plant gives trouble on the large scale, and occasionally the reverse is

found. The aim of model theory is to predict these scale effects and determine the conditions (if any) under which the performance of a model gives a reliable forecast of prototype performance. Quantitative methods of correlating the behavior of model and full-scale systems have been successful in other fields of engineering, notably the design of ships and aircraft, where processes occur that are too complex for mathematical analysis. Applied to chemical plant [and I interpret this to be the equivalent of metallurgical processes] such methods point to the possibility of larger scale-up factors, smaller and cheaper pilot plants, and more dependable results."

A usable model theory is founded on an understanding of the components of the process – an understanding that is independent of the specific equipment in which these data are collected. This concept and its application to design are the great contributions of chemical engineers and they have opened the way to rapid development of processes in the chemical and petroleum industries. By contrast, we in the steel industry have not devised effective pilot units or models of major components. And until we do, process developments and improvements will come very slowly and expensively.

Large Equipment – For example, our knowledge of the blast furnace (in any engineering sense) is tied quantitatively to a particular furnace. All proposals for design or process changes can be evaluated only on full-scale furnaces. This means that too few such ideas are ever tried and when they are tried the data collected over the narrow operating range available to the experimenter are generally too limited to have useful significance. (*Cont. on page* 174)

Book Review . . .

X-Ray Studies for the Student and the Practitioner

ELEMENTS OF X-RAY DIFFRACTION, by B. D. Cullity, Addison-Wesley Publishing Co., Inc., Cambridge, Mass., 1956. 514 p. $10.

*Reviewed by H. C. STUMPF**

THE AUTHOR'S PLAN is to introduce the subject to the student who has no previous knowledge of the field, supply him with a background in X-ray diffraction theory and teach him the methods and techniques used in the laboratory. Crystallographic aspects are treated in a summary manner, as are mathematical and theoretical details. The obvious target of the book is the student of physical metallurgy. Most of the applications pertain to physical metallurgy, and the emphasis is on methods rather than on metallic structure in some contrast to the well-known text by Barrett.

The book starts with four basic chapters describing the properties of X-rays, crystal geometry, and the diffraction of X-rays. Emphasis is placed upon the application of pertinent mathematical relations rather than derivation. The principles of the stereographic projection are outlined in this section.

Chapters are devoted to the Laue method, powder diffraction, and diffractometer measurements. A wide field is covered in limited space, including camera geometry, collimation, monochromatization, and counter performance. As

*Dr. Stumpf is head of the X-ray section, physical metallurgy div., Alcoa Research Laboratories, New Kensington, Pa.

background material the text makes interesting reading.

The remainder and major part of the book discusses applications. Included, among other topics, are crystal orientation, preferred orientation, parameter measurement, phase diagram studies, chemical analysis, and stress measurement. This section, in short, describes all of the X-ray diffraction techniques commonly used in metallurgical laboratories. Here will be found many of the details missing in earlier chapters.

At the end of each chapter are problems designed to illustrate and amplify the meaning of the text. The book closes with a list of recommended reference sources and a number of appendices including appropriate tables.

Used in conjunction with a well-supervised laboratory course, this book presents a well-rounded introduction to X-ray diffraction methods for the student of physical metallurgy. It provides suitable grounding for a student involved in a scholastic research project. Experience will soon teach him, however, that he has merely acquired the rudiments of the subject and that it will be necessary to consult more detailed references in regard to both diffraction theory and application, and to alloy structure. The author has succeeded quite well in his intent.

SMALL ANGLE SCATTERING OF X-RAYS, by Andre Guinier and Gerard Fournet, translated by C. B. Walker, John Wiley and Sons, Inc., New York, 1955. 268 p. $7.50.

*Reviewed by E. G. HANEY**

THIS TIMELY MONOGRAPH presents the most complete and authoritative account to date of both the theory and practice of small-angle scattering of X-rays. Other books or articles on X-rays treat the subject only in a limited manner, if at all. The contents are thoughtfully presented in six chapters consisting of a brief introduction, a comprehensive treatment of fundamental theory, description of experimental apparatus and techniques in detail, interpretation of experimental results, comparison with other methods, and a final chapter on applications. The text is followed by a bibliography of 569 titles, a revision of one issued in 1952 by the American Crystallographic Association. A majority of the papers listed are more recent than 1948, showing active interest in small-angle scattering over the past decade.

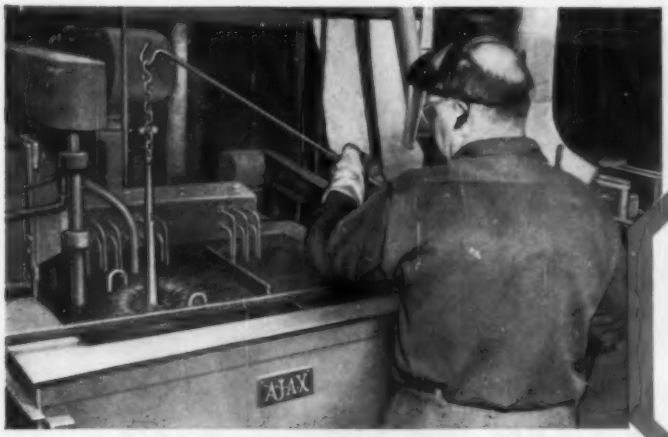
Small-angle scattering of X-rays, as the name implies, is observed within a few degrees of the primary beam, being a result of variations in electron density with a periodicity large compared with wave length. Since small-angle scattering is only related to the distribution of matter, a crystalline sample is not a necessary prerequisite for its application as in the case of X-ray diffraction. The angular distribution of the scattered intensity discloses the size and indicates the shape of fine particles of heterogeneous regions. The applications for this versatile physical technique include such diverse fields as biology, metallurgy, mineralogy, and chemistry, as illustrated by some of the "particles" studied — namely, viruses, proteins, carbon blacks, colloids, micelles, tiny voids in cold worked metals and precipitation nuclei in alloys. Perhaps as far as the metallurgist is concerned the most important application is in supersaturated solid solutions where the first stages of precipitation can be studied. Also the clustering of like atoms in equilibrium solid solutions can be detected.

The chapter on general theory is necessarily long since it covers about every possibility that can give small-angle scattering — for example, spherical particles, irregular particles, homogeneous and heterogeneous dispersions, and dilute solutions. However, the theoretical treatment assumes single scattering; the effects of multiple scattering, such as refraction and extinction, are ignored.

The book probably makes its most significant contribution in describing in detail the essential experimental requirements and the procedures necessary for the interpretation of results. In so doing, the authors disclose some fallacies in past treatments of experimental data. The authors are to be congratulated for clarifying such cases and pointing out the limitations of the method. As a result of their efforts, small-angle scattering now has a more solid foundation, but it would appear that more experience with both the method and the interpretations of results may be necessary before quantitative results can be considered reliable.

This book is recommended to all who should be aware of such new techniques and it should be consulted by those who are working in the field of X-ray diffraction. The last four chapters will be especially welcomed by nonspecialists in diffraction who are engaged in small-angle scattering or anticipate its use.

*Dr. Haney is research engineer in the X-ray section, physical metallurgy div., Alcoa Research Laboratories, New Kensington, Pa.



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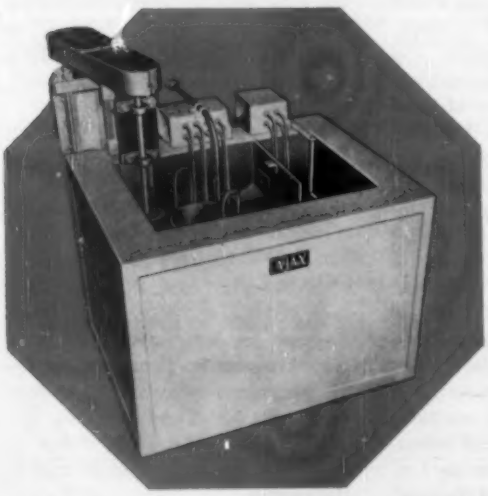

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Correspondence . . .

Brittleness of Carbides

COLUMBUS, OHIO

There could be some technical confusion over a sentence in Dr. Hausner's fine article in the January 1958 issue of *Metal Progress*. On p. 196 is the statement, "They [referring to Meerson and Samsanov] believe that the brittleness of the standard WK 3 tool with 3% cobalt binder is due to segregation of the WC-W_2C eutectic". Carbide technologists will recognize readily that Meerson and Samsanov just couldn't believe in such a hypothesis!

Perhaps the statement resulted from translation or over-condensation of the thought expressed in the paragraph in the paper by Meerson and Samsanov which can be translated in part as follows: "Attempts to increase the efficiency of hard alloy tools . . . by their preparation . . . from cast alloy of WC-W_2C eutectic . . . did not show positive results because of increasing brittleness. This is also the reason that . . . WK 3 (WC with 3% cobalt) has not found more extensive use."

R. B. FISCHER, Chief
Physical Metallurgy Div.
Battelle Memorial Institute

"Climate" for Crash Programs

AURORA, ILL.

The "Critical Point" about the invention of 4340 steel in the February issue is very good. It illustrates how technology is commonly applied. Few people are interested in better designs, materials or processes, no matter how superior they may be, if present designs, materials and processes are doing what is expected of them. It is when they fail to perform, sell or make a profit that new ideas – such as 4340 in place of 3240 – are eagerly grasped.

Try to sell the average man a life preserver and he puts up a lot of sales resistance. He is very certain he doesn't need it but when he falls into the water, he will clutch desperately at a straw. For similar reasons industrial progress develops in a slow, erratic and negative way, at a rate which is proportional to the number of emergencies which arise. At a time with few emergencies, creative people – scientists, inventors, designers, engineers – can beat their brains out and make their persistence thoroughly offensive to their associates and superiors by promoting developments which actually have a great deal of merit. If they have the foresight and patience to hold their creative ideas in reserve, but on the tip of their tongues, when emergencies do arrive, they may become the heroes of the hour. If no emergency arises, the idea may never have an opportunity to be put into effect. Under this usual procedure, progress is only a small fraction of what it might be.

In an emergency, 4340 was created in 5 min., but if it had taken 5 hr., it is unlikely it would have been fatal. With sputniks traveling 5 miles per sec. and nuclear reactions in 5 millionths of a second releasing more energy than was used in several dozen major wars of the past, we do not have even 5 sec. to find the solution to the emergencies which from here on can face us at any instant.

It appears that to be safe in the future, we must anticipate our emergencies and find solutions to them well in advance. This calls for individuals with the very maximum of vision, ingenuity and creative ability. It is certainly no assignment for complacent and unimaginative conformists who have little conception of, and less desire for, a changing universe.

It is probable that the fundamental principles of psychology, tactfully applied to human emotions for the promotion of understanding and cooperation and alleviation of prejudices and antagonisms among different groups, can be far more effective in preventing cataclysmic emergencies than can nuclear physics, metallurgy and chemistry in creating interstellar space ships and unlimited energy production. In this same vein of thought follows the editor's "A Thought on Sputnik" in the same February issue of *Metal Progress*.

E. H. SNYDER

Damage by Uncontrolled Shot Blasting

OTTAWA, CANADA

It is unfortunate that my short note on the above topic in *Metal Progress* for February, p. 92, contained two errors. [EDITOR'S NOTE – These errors were made by the editor, not Mr. Kornfeld.]

The crack in Fig. 2 is due to hydrogen, not to fatigue as said in the caption.

The hardness number 275 quoted near the bottom of the first column is diamond pyramid number, rather than diamond penetrator number, as printed.

KONRAD KORNFELD

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Personal Mention

Jerome Strauss

After 30 years with Vanadium Corp. of America, JEROME STRAUS has retired as vice-president. His retirement, however, will not mark the cessation of his interest and activity in metallurgy; he will be undertaking a limited amount of consulting work both here and abroad, and only recently returned from a trip to Europe in connection with this work.

Born in New York in 1893, Strauss received his metallurgical engineering degree from Stevens Institue of Technology. Following graduation, he worked in the metallurgical department of Illinois Steel Co. for a year and then joined Western Drop Forge Co. as a chemist and metallurgist. Called into the Army during World War I, he served as a lieutenant in the Ordnance Dept., and after his discharge spent a number of years at the Naval Gun Factory.

Beginning his career at Vanadium in 1928 as chief research engineer, he soon rose to vice-president and held this post for over 20 years. During his years at Vanadium, Mr. Strauss has been responsible for many far-reaching developments in steelmaking. He made a major contribution in the initial use of low-alloy high-strength plate and sheet steel, and the development of the boron-treated steels.

In recognition of his contributions to the metallurgical field in the past 40 years, he was named the A.S.T.M. Gillett Memorial Lecturer in 1953, and the Burgess Memorial Lecturer of the Washington Chapter two years later.

As an active member of many technical organizations, he has served as chairman of the Washington and Pittsburgh Chapters and he is currently chairman of the A.S.T.M. standing committee on corrosion resisting steels which he organized. In addition he has held executive offices in the American Foundrymen's Society and on the Welding Research Council.

Harry Majors, Jr., formerly a professor at the University of Alabama, is now head of the mechanical engineering department at Seattle (Wash.) University.

Wesley R. Kegerise has been appointed metallurgist, high temperature alloys, by the Carpenter Steel Co., Reading, Pa. He joined Carpenter's metallurgical laboratory in 1949, and in 1953 was chosen to head high temperature and special alloy development in the research laboratory.

Joseph C. Danec has accepted an appointment as supervisor of sales of abrasive products for the masonry and concrete trades of the Norton Co., Worcester, Mass. He joined Norton in 1941 and until his recent promotion was technical assistant to the production engineer of Norton Behr-Manning Overseas, Inc., the Norton division which handles foreign sales and production at overseas plants. Mr. Danec is a past chairman of the Worcester Chapter.

Robert E. Hopper is stationed at Rawalpindi, Pakistan, as U. S. Army technical advisor, metallurgical division. His duties include establishing a metallurgical laboratory and training technicians.

Willard R. Pratt, formerly vice-president of Bonded Diamond Products of Worcester (Mass.), Inc., recently became president of Vanguard Abrasive Corp., LeRoy, N. Y., a new concern engaged in manufacture of diamond abrasive products.

George G. Karian has been appointed manager of iron powder sales for the Alan Wood Steel Co., Conshohocken, Pa. He was formerly product manager in charge of sales of powder metal and industrial compacting presses for F. J. Stokes Corp., Philadelphia.

Andrew F. Kravic has joined the nonferrous section of the nickel sales department of the International Nickel Co., New York, where he will devote his attention to powder metallurgy, particularly the sales and promotion of carbonyl nickel and carbonyl iron powder. Before coming to Inco, he was an instructor in metallurgical engineering at the Polytechnic Institute of Brooklyn.

John Marple, sub-branch manager at the Baltimore branch office of Whitehead Metal Products Co., Inc., New York, since 1946, has been transferred to Philadelphia as sales manager. He joined Whitehead in 1931 as one of the company's first salesmen in the Philadelphia area and remained in that branch until moving to Baltimore.

V. G. Asdikian, formerly affiliated with L-R Heat Treating Co., has accepted a position as general manager of Scientific Steel Treating Corp., Newark, N. J.

Ray Neff has been named southern Florida sales representative by Latrobe Steel Co., Latrobe, Pa. Formerly chief engineer with Adams Engineering Co. in Miami, Mr. Neff will make his headquarters at Latrobe's Miami branch office in Hialeah, Fla.

Cyril J. VandeWater has been appointed director of manufacturing of the A-S-R Products Corp., New York, formerly American Safety Razor Corp. Mr. VandeWater joined A-S-R early in 1957 as chief process engineer after 11 years of service with the Maytag Co. in Newton, Iowa, where he was chief methods engineer.

Hamburg Tang was recently elected vice-president of Alloys Unlimited Inc., New York. Before coming to Alloys Unlimited, Mr. Tang was affiliated with research and development department at the Republic Steel Corp. plant in Buffalo, N. Y., and Alpha Metals, Inc., Jersey City, N. J.

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Centrifugally-cast Fahrite alloy tubes for roller shaft assemblies, tubular furnace hearths and radiant heating installations. Many sizes of Fahrite tubes can be centrifugally-cast from Ohio Steel's permanent mold equipment. Fahrite U-bends also are available for use with tubes in radiant heating installations. Centrifugally-cast tubes are available in many grades of Fahrite to meet your exact operating conditions.

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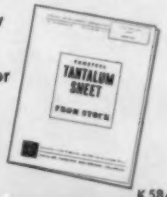
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NORTH CHICAGO, ILLINOIS, U. S. A.

Personals . . .

Harry P. Troendly has been elected a group vice-president of Borg-Warner Corp., Chicago. Mr. Troendly has been president of the corporation's Spring Div. since 1953 and prior to that had been vice-president and general manager since organizing the division in 1940.

Victor Brown, an executive vice-president of Kropp Forge Co., Chicago, has been elected president and general manager of Kropp Steel Co., the firm's wholly owned subsidiary in Rockford, Ill. Mr. Brown joined Kropp in 1942 as chief metallurgist and was elected a vice-president in 1953.

William N. McArdle has been appointed sales manager of the Philadelphia district of the Superior Steel Div., Copperweld Steel Co., Carnegie, Pa. Until recently, Mr. McArdle was manager, aircraft products, for U. S. Steel Supply Div. of U. S. Steel Corp. and prior to that served as Chicago district sales manager for Jones & Laughlin Steel Corp. and Rotary Electric Steel Co.

L. D. Gable has resigned as general manager of Timken Roller Bearing Co., Canton, Ohio, to act as consultant in his own company. He will be succeeded by **Walter Kramer**, formerly factory manager and past chairman of the Columbus Chapter.

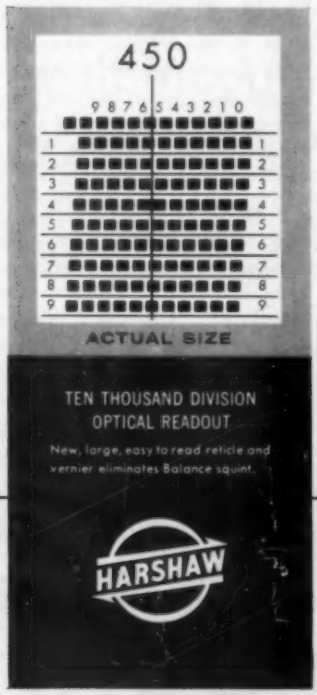
David Rosenbaum, formerly senior technical assistant at Battelle Memorial Institute, Columbus, Ohio, is now metallurgical engineer of the aircraft division of Surface Combustion Corp. in Columbus.

O. W. McMullan, newly appointed director of research and development of the Bower Roller Bearing Div., Federal-Mogul-Bower Bearings, Inc., Detroit, is directing the expansion and centralization of the company's research and development department. Mr. McMullan has been chief metallurgist for Bower since he joined the company in 1944.

Harold D. Swarr has accepted a position as technical assistant in the openhearth department of Lukens Steel Co., Coatsville, Pa. Before coming to Lukens, he was employed at Bethlehem Steel Co.

Weighing is the heart of all analytical procedure

To keep pace with increased laboratory work loads balance manufacturers have developed balances that weigh faster, are easier to operate and require *no operator technique*. The NEW Christian Becker Model NA-1 single pan, semi-automatic balance provides everything the chemist has wanted. Fast accurate weighings are as easy as 1 - 2 - 3.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New, large, easy to read reticle and vernier eliminates Balance squint.
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1. Place sample on pan, close door, select "rough weighing" beam by rotating knob "A".
2. Weight control knobs "B" are then rotated. Weight indicator lights "C" *indicate if weights have to be added or removed.*
3. Final 1000 mgs., or any part thereof are recorded on new, large, easy to read reticle and vernier, after fine weighing beam is put in use. This ten thousand division optical readout "D" is absolutely unique. It eliminates completely "balance squint." The large number at the top plus the vertical line show that the weight is between .455 and .456 gram. By following the line down, it makes a solid rectangle at "4", thus giving a reading of .4554. This plus the weight recorded on counter "E", gives total weight of sample.

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- Weighing and pilot lights to indicate beam in use
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- Knobs for weights and beams are at convenient table height
- Weight counter and reticle and vernier are at eye level.

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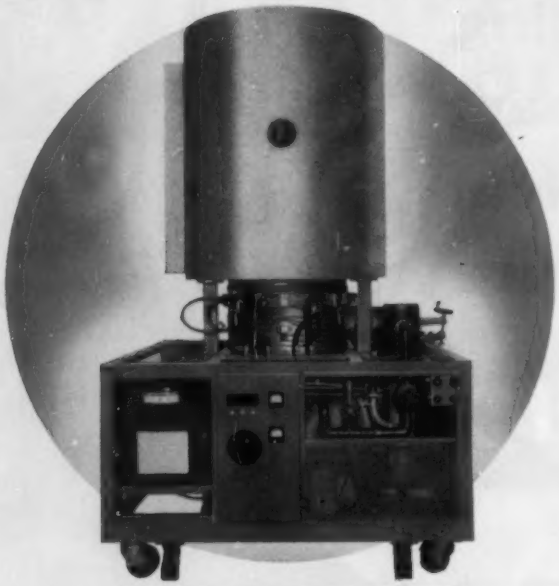

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The approach of KINNEY engineers to modern High Vacuum techniques is based upon many more years of Vacuum "know-how." This is reflected not only in the practicality of the equipment but in the economic advantages in design, operation and maintenance, as well. Write for outline of advanced techniques in vacuum heat treating, or better still, make a date to discuss your Vacuum Furnace problems today!

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Personals . . .

Herbert E. Peterson recently joined the staff of Instrument Engineering and Combustion Equipment Co., Rockford, Ill.

Harry B. Burrack has been appointed technical superintendent of the Olin Aluminum Div. rolling mill of Olin Mathieson Chemical Corp., located near Hannibal, Ohio. Mr. Burrack, who has had 17 years experience in the aluminum industry, will supervise quality control, metallurgy, chemistry and testing.

John R. Townsend, special assistant, Office of Assistant Secretary of Defense (Research and Engineering), Washington, D. C., has been elected vice-president of the American Standards Assoc., succeeding **Van H. Leichliter**, president of the American Wire and Steel Div., U. S. Steel Corp. Mr. Townsend was formerly director of materials and standards engineering for Sandia Corp., Albuquerque, N. M.

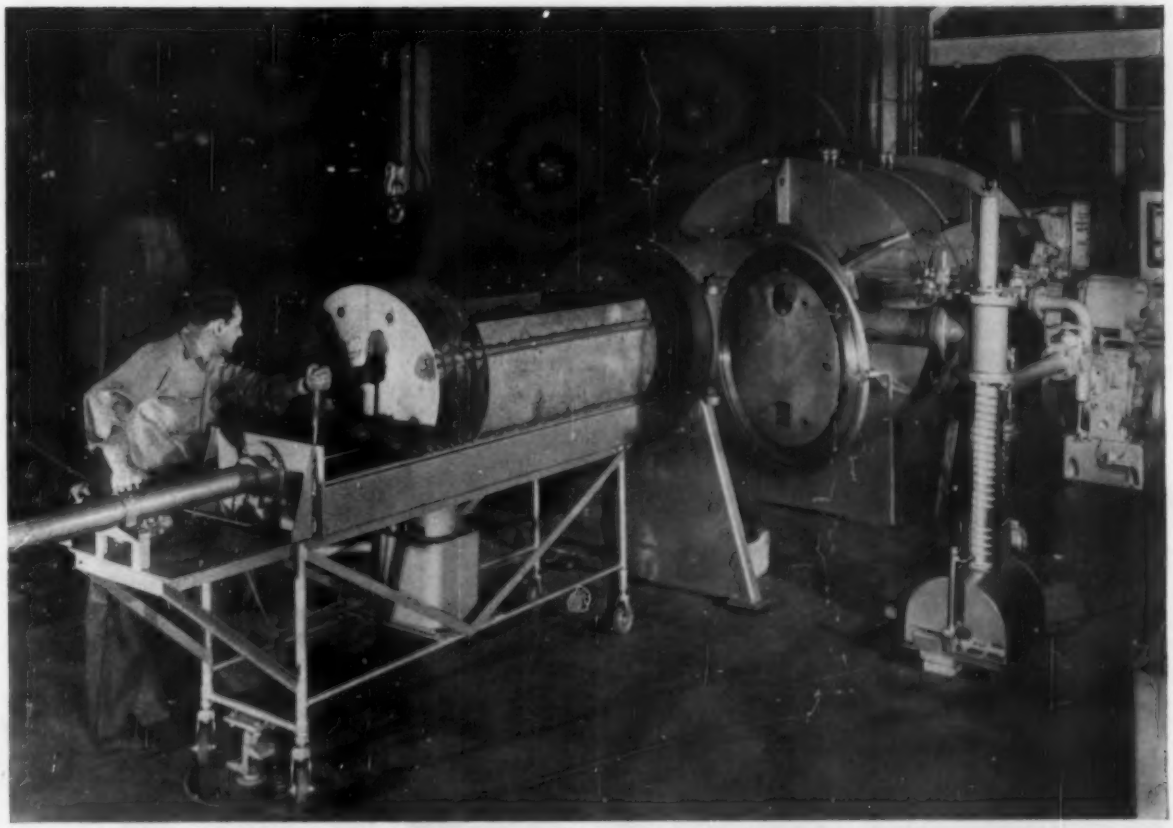
Robert C. Hessinger has joined the staff of the powder metallurgy department of Vanadium - Alloys Steel Co., Latrobe, Pa., as a metallurgical engineer.

H. J. Nichols has been appointed research engineer, welding, at the Applied Research Laboratory of U. S. Steel Corp., Monroeville, Pa. For the past 15 years Mr. Nichols was head of the welding and radiography section of the physical metallurgy division, Dept. of Mines and Technical Surveys, Ottawa, Ont.

B. H. Alstad has accepted a position as sales engineer in the Texas-Oklahoma - Louisiana - Arkansas district for Parker-Hannifin Corp., Cleveland. Mr. Alstad was sales manager of Riverside Tool Co., Chagrin Falls, Ohio, before joining Parker-Hannifin.

Cullie J. Sparks, Jr., formerly with the Kentucky Research Foundation, Lexington, Ky., recently joined the staff of Oak Ridge National Laboratory, Oak Ridge, Tenn.

Charles Arthur has been transferred from the Sandia Corp.'s Albuquerque, N. M., operation to the corporation's Livermore Div., Livermore, Calif.



Loading Zone. Hydraulic ram drives movable work boat into the two-temperature-zone vacuum chamber of new Stokes furnace equipped with Inconel nickel-chromium alloy retort at the Martin Company plant, Baltimore. Suitable for vacuum brazing, annealing and degassing, the electric alloy heated unit can maintain operating temperatures over 2000°F at pressures as low as .2 microns.

Designers equip new Stokes vacuum furnaces with Inconel retorts for Martin experiments

Horizontal retort vacuum furnaces come *bigger* these days.

And *better*, too! Among other reasons, because designers and builders are standardizing on retorts of Inconel* nickel-chromium alloy . . .

Typical of this trend is the furnace shown here. It was designed and built by the Vacuum Equipment Division of F. J. STOKES CORPORATION, Philadelphia, Pa. The unit is one of two identical furnaces in operation at THE MARTIN COMPANY, Baltimore, Md.

Right now, Martin uses them mostly for experimental and limited-scale production vacuum brazing of aircraft components. But if they wish, they can easily switch to vacuum de-gassing, annealing or other heat treating operations.

The furnace structure, supplied by LINDBERG ENGINEERING COMPANY, Chicago, Ill., has a refractory-lined outer wall. In use, the space between the vacuum retort wall and the outer furnace shell is evacuated to approximately 500 microns. This reduces external forces on the Inconel alloy retort where pressures inside the retort drop to as low as .2 microns at temperatures in excess of 2000°F.

Retort material must have the strength to hold long-continued high vacuum at heat . . . resist thermal shock from rapid cooling . . . withstand corrosive atmospheres. *Inconel alloy does all these things.* And does them well!

In addition, it simplifies furnace construction. Its good "hot strength" helps in practical design. And Inconel alloy can be readily worked and welded to give a strong vacuum-tight joint that *stays* gas-tight.

For information on the use of Inconel alloy in heat treating equipment, write Inco for our informative booklet, *"Keep Operating Cost Down When Temperatures Go Up . . ."*

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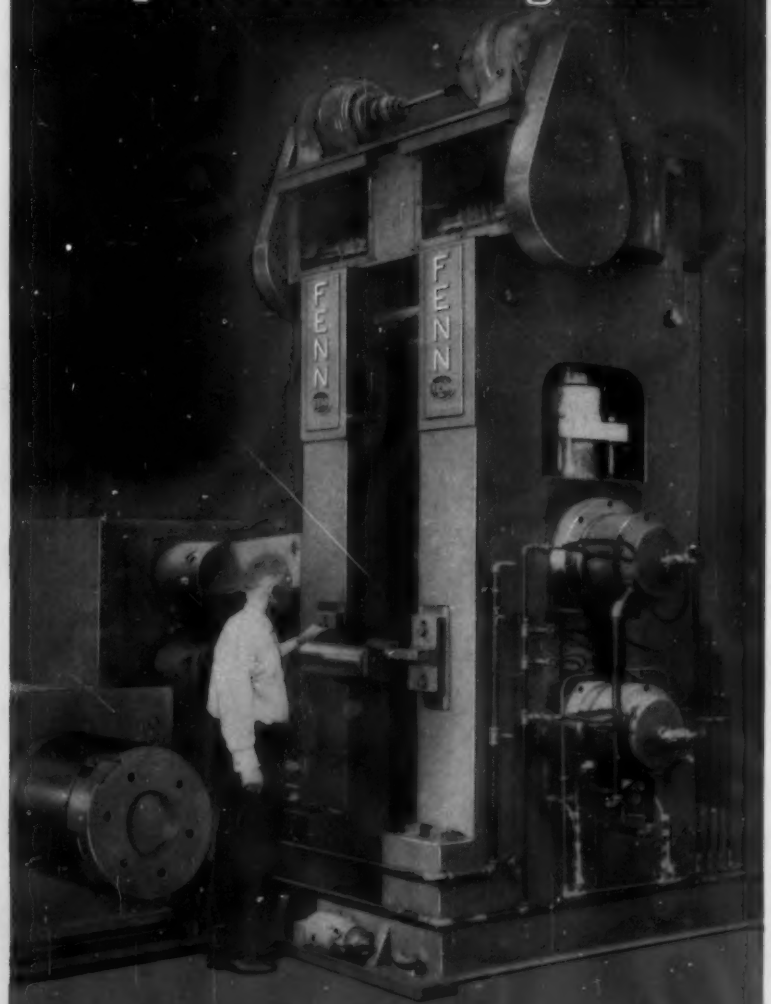

The inherent design of Fenn Rolling Mills achieves greater flexibility . . . extremely high separating forces . . . with dependability that only building to the highest quality standards can provide. Typical is the large heavy duty Fenn Precision Rolling Mill illustrated above. A combination Two-High/Four-High mill, with 16½" diameter rolls, it offers extreme versatility in rolling new alloys with high tensile strengths and is adaptable to either hot or cold rolling.

THE FENN MANUFACTURING COMPANY • 504 FENN ROAD • NEWINGTON, CONN.

Personals . . .

Several ASM members were honored by the American Foundrymen's Society at the Society's 62nd AFS Castings Congress and Foundry Show in Cleveland this month. **Ralph A. Clark** ASM and **Howard J. Rowe** ASM received gold medals, the highest award conferred by the Society. Mr. Clark, manager of foundry service, Electro Metallurgical Co., Cleveland, was awarded the Thomas W. Pangborn Gold Medal "for outstanding contributions to the Society and to the ferrous castings industry, especially in the field of gray iron metallurgy". Mr. Rowe, chief metallurgist, castings division, Aluminum Co. of America, Pittsburgh, was recognized "for outstanding contributions to the Society and to the light metals branch of the castings industry" and received the William H. McFadden Gold Medal. Awards of Scientific Merit were presented to **Kenneth H. Priestley** ASM, president, Vassar Electroloy Products, Inc., Vassar, Mich., **Franklin B. Rote** ASM, technical director, Albion Malleable Iron Co., Albion, Mich.; **Frank S. Brewster,** director of research and development, Brumley-Donaldson Co., Huntington Park, Calif.; and **Fred G. Sefing,** metallurgist, development and research division, International Nickel Co., Inc., New York.

M. Szczepanski ASM has joined the Abrasive Dressing Tool Co., Detroit, as director of the research and development laboratory. Mr. Szczepanski was formerly laboratory manager and chief metallurgist for E. E. Kaye, Ltd., Enfield, England.

Ward F. Simmons ASM has been appointed chief of the high-temperature metals research division at Battelle Memorial Institute, Columbus, Ohio. In his new position, he will take charge of research in the area in which he has been active at Battelle for the past 17 years.

Frank H. Vandenburgh ASM is the new president and chief executive officer of Mallory-Sharon Metals Corp., formerly Mallory-Sharon Titanium Corp. Mr. Vandenburgh was vice-president and general manager of Mallory-Sharon Titanium Corp. until the company was reorganized recently.

typical large drill bit

Surface metal is cut away to shape drill point and spiral flutes — core is exposed to wear, structural loads

Point and cutting lips are critical to drill performance. If alloy has any weakness at center, poor cutting or broken drill will result. Mel-Trol helps to solve this problem by providing greater strength and toughness at the core. Never before have commercially available alloys been as free of segregation, porosity and centerline weakness.

MEL-TROL®... alleviates a major metalworking problem—poor centerline quality in alloys

The more surface metal you cut away from an alloy steel bar, the more important uniform core quality becomes. The drill illustration above shows you why.

In alloy steels made by conventional steelmaking process, segregation, porosity or other inhomogeneities are often found along the centerline. Result: the core metal lacks the toughness of the rest of the bar, even though it may show no detectable variation.

To alleviate this major cause of poor tool quality, poor tool life and excessive rejects, Carpenter metallurgists developed the Mel-Trol process. Now, for the first time, alloys with greater uniformity from surface to centerline are being made in quantity.

The Mel-Trol process provides greater freedom from segregation, porosity and centerline weakness through a system of quality controls which play a part in every phase of the entire steelmaking process. Equipment developed specifically for Carpenter is used together with the most modern standard quality control tools. Every piece of equipment is used to its highest accuracy—nothing less.

Mel-Trol alloys are now available at Carpenter mill-branch warehouses. Ask about them the next time a Carpenter representative calls on you. He'll show you how you can join the growing number of companies who are finding Mel-Trol alloys the answer to a host of metalworking problems.

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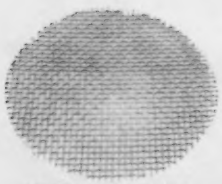
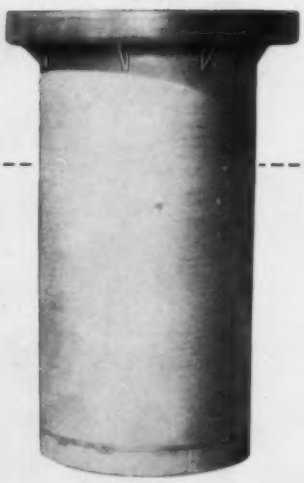


SCREENS AND GRIDS

BASKETS



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The best way to gain these benefits is to try us out on your next order . . . either for "standardized" items or special needs. A letter or 'phone call will get prompt action.

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Easier Operation, Lower Cost

SRL 59

Personals . . .

James O. Vadeboncoeur has been named marketing manager, western region, of the newly established west coast sales office of Sylvania-Corning Nuclear Corp., New York. The new office will be in Burlingame, Calif. Mr. Vadeboncoeur had been associated with the naval nuclear program of the atomic power division of Westinghouse Electric Corp. since 1952 as supervisor of central production, planning and control, of nuclear core manufacturing at Westinghouse's Bettis Field plant in Pittsburgh.

Neil J. Culp and **Samuel M. Purdy** have been promoted to supervisory posts in the metallurgy department of Carpenter Steel Co., Reading, Pa. Mr. Culp, who joined Carpenter in 1952, has been named supervisory metallurgist, alloy development, while Mr. Purdy is supervisory metallurgist, metallography, in charge of all metallographic and crystallographic activities in the company's research laboratory.

Robert P. Jensen has been promoted to sales manager of the foil and container division of Kaiser Aluminum & Chemical Sales, Inc., with headquarters in Chicago. He has been with Kaiser Aluminum since 1954 and has served as district sales manager in Philadelphia and Boston and as branch manager in Baltimore.

Ludwig Anselmini is a new staff member of the stainless steel and heat resistant alloys section of the development and research division, International Nickel Co., Inc. For the past three years Mr. Anselmini was a metallurgical design specialist with Republic Aviation Corp., Farmingdale, N. Y., directing the metallurgical engineering research. He is concurrently serving as part-time faculty member of the metallurgical engineering division of the Polytechnic Institute of Brooklyn.

Charles L. Bronson has been named head of a new research and development laboratory for Varel Mfg. Co., Dallas, Tex. For the past two years, Mr. Bronson has supervised installation of a new heat treat plant for the company. He was formerly chief metallurgist in the laboratory and heat treat departments of R. G. LeTourneau Corp., Longview, Tex., and Peoria, Ill.

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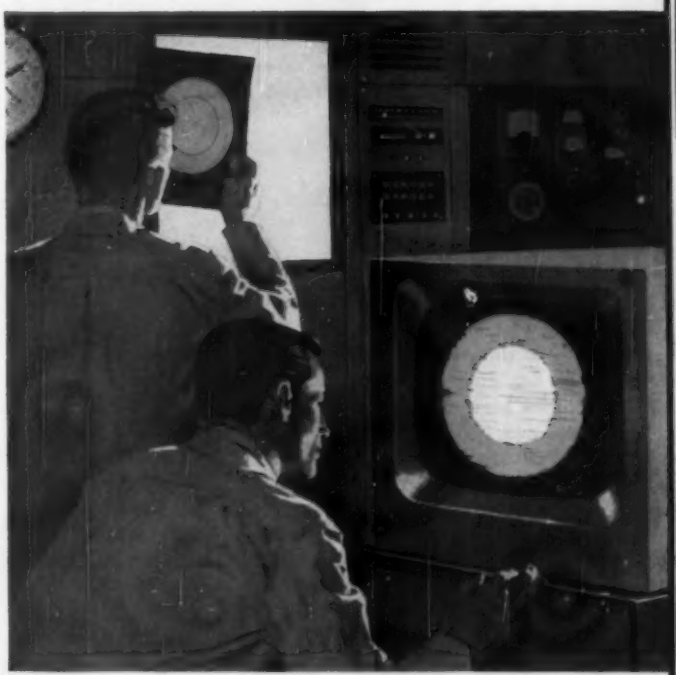

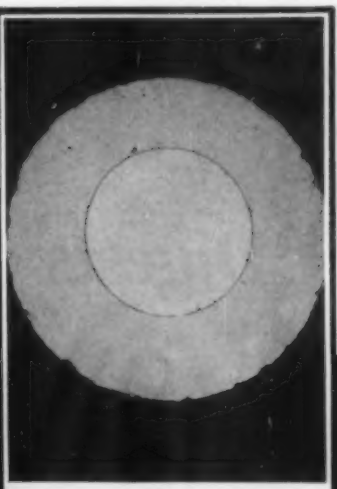

Actual photograph of gray-scale test transparency, shown unenhanced.

The same transparency showing gray-scale contrast enhancement by EXICON.

New Philco EXICON dramatically improves gray-scale contrast on any photographic transparency.

EXICON is proving an invaluable new tool in metallurgy, quality control, stress analysis and countless industrial applications. This new dimension in contrast enhancement is finding application wherever greater detail is desired in the reading of any photographic negative. If you have a problem requiring contrast enhancement . . . Philco's new EXICON system may provide the answer.

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At Philco, opportunities are unlimited in electronic and mechanical research and engineering.

Digests of Important Articles

Better Test for Ductile Iron

Digest of "Modified Keel Block Design for Ductile Iron Acceptance Tests", by Gilbert McGlothlin, *The Iron Worker*, Vol. 22, No. 1, Winter 1957-58, published by Lynchburg Foundry Co., Lynchburg, Va.

LYNCHBURG FOUNDRY CO. began experimental production of ductile iron in 1949. The metallurgical control laboratories found the physical testing procedures for it to be more complex than those required for gray iron. Due to the characteristics of ductile iron, a form of test bar or block, other than the conventional A.S.T.M. "Y" and "keel-type" test blocks used for gray iron, was necessary to obtain a sound test specimen entirely free of center line shrinkage.

The keel-type test block consists essentially of a block of iron about 8 in. long with two protruding legs which are parallel for its full length. These so-called legs, when removed, become test coupons, X in. square by 8 in. long. The value of X will be ½ in., 1 in. or larger depending on the section thicknesses of the castings involved.

The "Y" type test block is similar and is so named because its end view resembles the letter "Y". Test coupons are taken from the leg portion of the block. The top part of the "Y" serves as a feeder throughout solidification to prevent any porosity in the leg. Both types of test blocks are poured with the legs downward.

The leg, or test coupon, is parted from the block body by a milling operation. It is placed in a lathe where a tensile test specimen is turned. The specimen is threaded or shouldered on both ends, depending on the type of holder used in the testing machine, with the 2¼ in. in the middle highly polished to a final diameter of 0.505 in.

The use of the keel block for test purposes was expensive, and laboratory results were delayed by excessive time involved in removing the legs from the body of the block. The operation required a machine to saw or mill the legs, or the use of a shaper to part the leg from the body. Few laboratories have such facilities within their own department which makes it necessary to depend on machining departments. Machine shop scheduling created a bottleneck which delayed physical testing results and made evident the need for a simplified test block.

The first modified design employed the 1-in. A.S.T.M. keel block dimensions, and by the use of a wafer-core arrangement similar to the Washburn risering technique, a parting notch was cast in the side of the keel permitting either, or both, legs to be knocked off with a heavy hammer blow.

The wafer-core opening was found to be critical. If the width of the opening was reduced below ¼ in., shrinkage was detected in the test coupons; whereas a wider opening to correct for shrinkage made it difficult to remove test coupons with a hammer. Experimental tests made by comparing the modified keel block with the standard A.S.T.M. keel block disclosed similar physical properties.

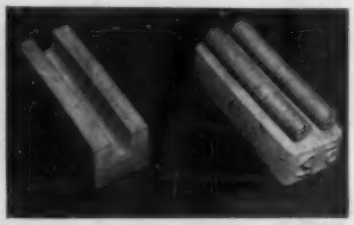

Fig. 1 — Comparison Between the A.S.T.M. 1-In. Keel Block (Left), and the Modified 1-In. Round-Leg Keel Block (Right)

Fig. 2 — The Round-Leg Keel Block Core (Left), Ready for Pouring, and a Section of the Core

With the knowledge that a wafer-core opening with a width of ¼ in. would successfully feed each leg, an effort was made to further improve the modified block by substituting 1-in. round legs for the 1-in. square ones. The 1-in. round bar would provide a more efficient shape for the lathe and would offer the advantage of less stock to be removed in turning a tensile specimen. It was found that a 3/16-in. feeder connection was sufficient to produce a sound specimen. The design of this block was then such that the round leg would shear away cleanly upon impact of a hammer blow.

This modification, when perfected, looked promising insofar as surface imperfections, internal soundness, and shape were concerned. Figure 1 shows the round-leg block pictured alongside the conventional square-leg type. In Fig. 2 the core used to form the round-leg keel block is shown. Fig-

See it at the Show*

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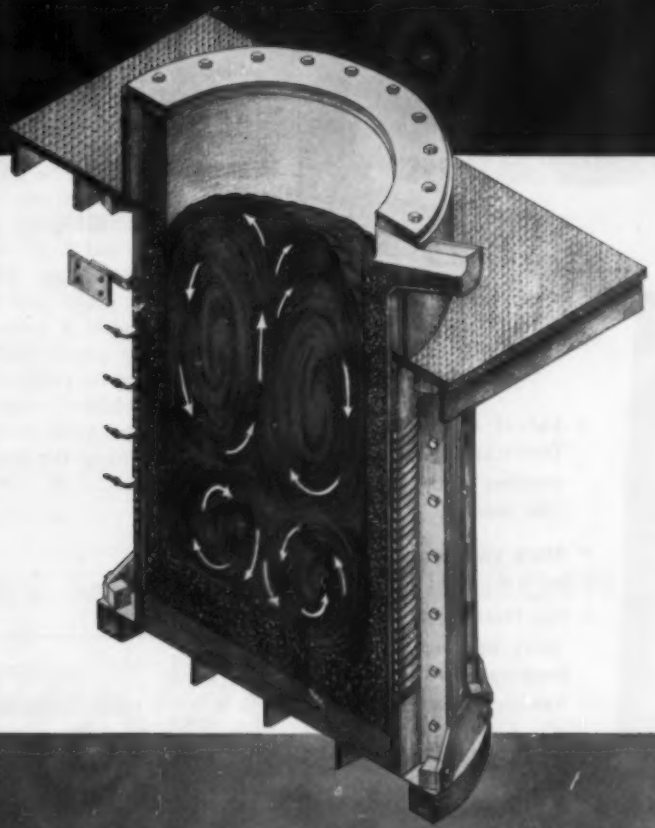
CORELESS 60 CYCLE INDUCTION MELTING FURNACE



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Test for Ductile Iron . . .

ure 3 shown below is a drawing showing the dimensions of the modified keel block core.

When the dry sand core mold is poured completely full of iron, there will be no shrinkage in the two legs. It is important that the small thin wafer core be glued securely and held in its proper position. If it is not, the center portion will break loose and float when the cavity is filled with iron. The legs then become a major part of the block which renders it useless.

Work on this project had now reached the point for evaluating the merits of the modified version. A series of tests were made comparing physical properties of the metal obtained from an A.S.T.M. 1-in. keel block with those from the modified round-leg block. Comparison test specimens were poured from the same ladle of ductile iron. The ultimate tensile strength values of the modified keel block were consistently 3 to 5% less than those obtained from the A.S.T.M. keel block. In most cases the difference in values for yield point, per cent elongation and reduction in area was negligible. During this development period, a number of modified keel blocks were poured and tested by other foundries. Their reports verified the findings of our own laboratories.

Approval was given for use of the modified keel block in all cases except where specifications called for A.S.T.M. 1-in. keel blocks or other specific test specimens. Figure 4 shows a ductile iron test specimen

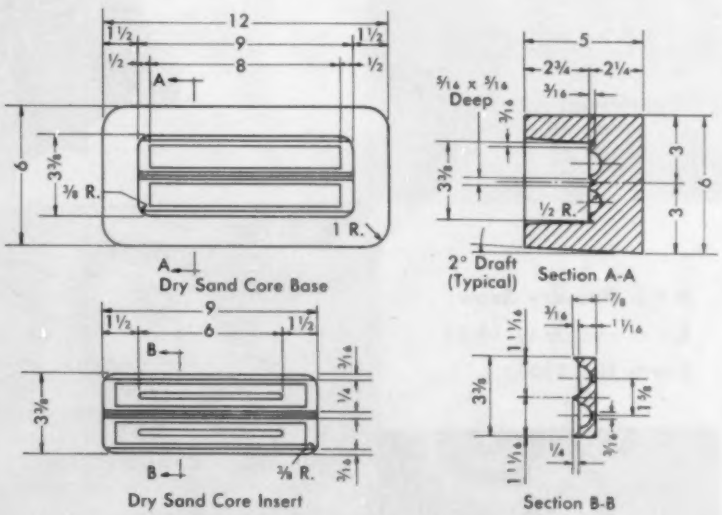


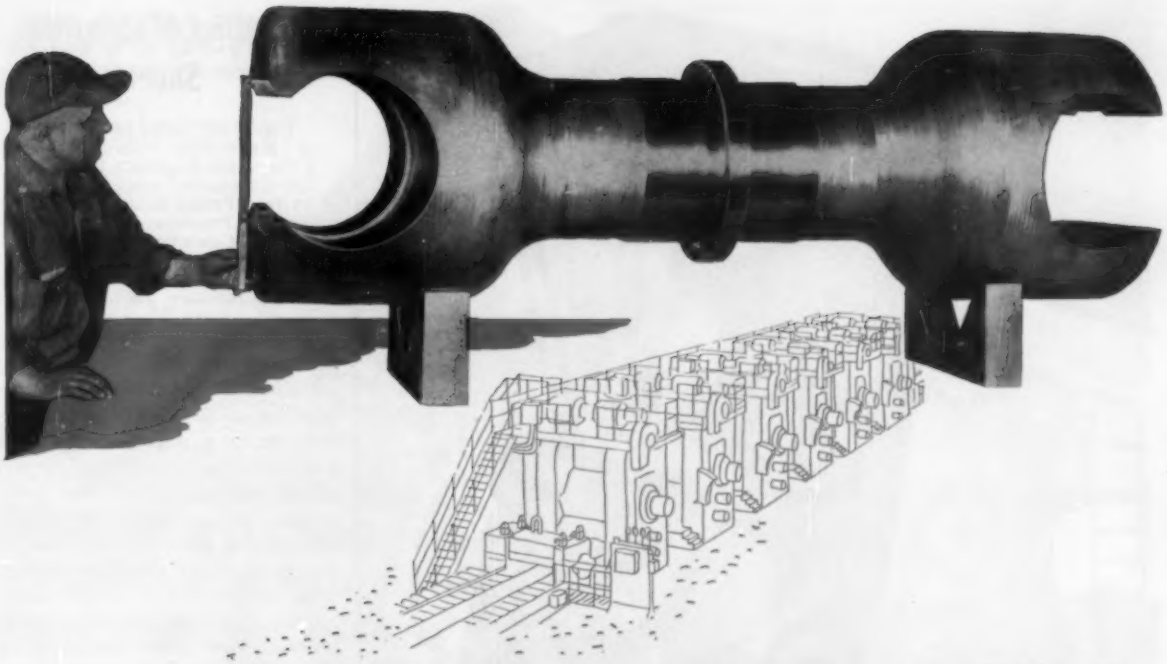
Fig. 3 – Drawing Shows Dimensions of the Modified Keel Block Core (With Round Legs), and in Two Parts

Fig. 4 – The Round Leg From the Modified Keel Block Showing the Ductile Iron Test Specimen as Taken From It. The specimen is ready to be placed in the tensile testing machine

taken from the round leg from the modified keel block.

The time saved by eliminating a machine operation in separating the legs from the body of the block (16.8 min.) plus decreased time interval in lathe operation due to less stock resulting from a round leg proved a substantial savings.

The modified keel block has now been in regular use at Lynchburg Foundry Co. for the past two years. It is well established that this keel block in its present stage of development offers a most economical and efficient form of test block for ductile iron control. A. G. G.



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When you are considering cylinders, spindles, driveshafts, or any special purpose forging, whether rough turned or finish machined, call your local Finkl representative. He will be glad to help you plan, or call upon the more than 78 years of Finkl experience to save you money and give you the finest forgings, or die blocks, available.

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Bonding Magnesium Sheet

Digest of "Adhesive Bonding of Magnesium — Incorporating a Corrosion Resistant Hot Alkaline Chromate Treatment as the Surface Preparation", by R.J.E. Hunter. Presented at a meeting of the Committee on Bonded Structures, Society of Aircraft Materials and Process Engineers, January 1957, Preprint No. 41. 13 p.

Avro Aircraft Ltd., Toronto, has adopted metal-to-metal adhesives for use in primary parts of aircraft structure, since they provide a means to reduce weight without sacrificing strength. In addition, more uniform stress distribution results. Although no great difficulty was experienced in the metal bonding of 2024 and 7075 aluminum alloys, considerable development work was necessary before the metal bonding of magnesium alloys could be similarly perfected.

In the present application, a magnesium sheet alloy – ZE 41 containing 4% Zn and 1% Ce, in condition H 24 and in thicknesses from 0.032 to 0.080 in. – is being bonded to doublers, boundary angles and stiffeners. A complication in the bonding process is that protective treatment of the magnesium cannot be carried out after bonding. For one reason, metal-to-metal adhesives have very little strength if applied to bare magnesium alloy surfaces. Thus, pretreatment is necessary.

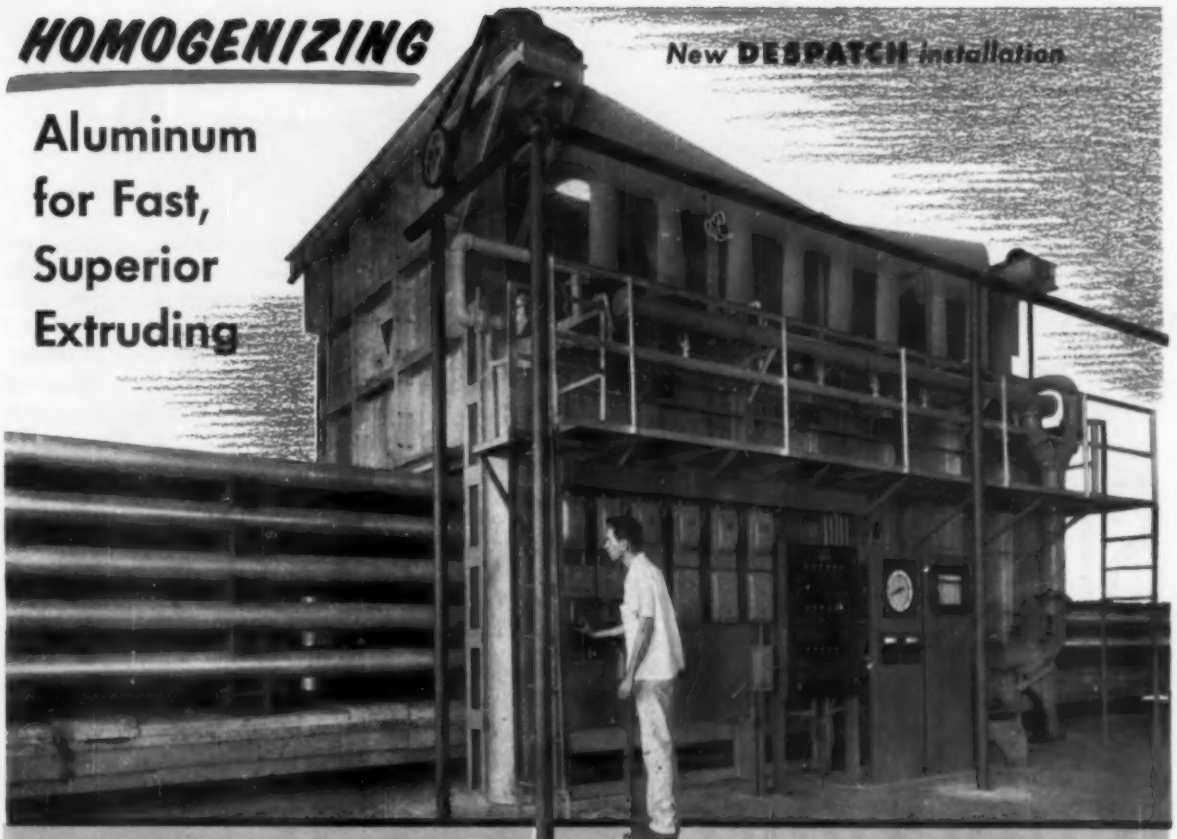
A ceramic type of anodic coating, very attractive from an application point of view, provided a very good bonding surface, but its tendency to deep pitting under severe corrosive conditions was a serious deterrent.

The hot alkaline chromate treatment, closely resembling the Dow 8 treatment, has been in standard use at Avro for many years, mainly on castings; while giving good corrosion resistance under standard paint, it gave very poor results when corrosion was present at the metal bond interface. The standard four-finger-type test piece used in MIL-A-5090 B gave acceptable peel strength values with this protective treatment and the standard bonding cycle and cure used with Narmco 4021 adhesive. On components having larger bonded surfaces, the peel strength of

(*Continued on p.* 134)

HOMOGENIZING

Aluminum for Fast, Superior Extruding



GULFPORT WORKS—ALUMINUM DIV. OLIN MATHIESON CHEMICAL CORP.

now produces substantial quantities of extrusions for window frames, trailers, architectural applications etc.

Fast Extruding Now Possible

Before, Olin Aluminum had problems extruding their non-homogenized alloys. The "logs" had to be slowly and cautiously extruded in order to minimize unsightly tear marks. These surface imperfections were a practically unavoidable result of extruding aluminum having uneven construction.

Now, by thoroughly homogenizing their aluminum alloys in the new DESPATCH furnace shown above, the company extrudes at a rapid rate, boosting production of extrusions with uniform physical construction, and with a superior surface quality.

Let DESPATCH *help you!*

PRECISE TEMPERATURE IS NEEDED

This indirect gas fired, radiant tube recirculating DESPATCH furnace holds a temperature of 1100°F. within very close limits enabling the Olin Aluminum Gulfport Plant to produce an even, homogeneous blend in their aluminum alloys for extruding.

A typical load is 50 to 60 aluminum "logs", each weighing about 1,000 pounds, 18 ft. long with diameters of 6", 8" and 11".

Each load stays in the homogenizing furnace 16 hours. Once the logs are in the furnace no supervision is necessary. Constant temperature is assured, thanks to efficient firing and sensitive automatic controls.

Write for complete information on Despatch aluminum solution heat treating furnaces, homogenizing furnaces, aging ovens, etc.

Write for Bulletin No. 81P

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PIONEERS IN ENGINEERING HEAT APPLICATIONS FOR INDUSTRY

big or small, Surface mechanized furnaces pay off

Whether your volume is modest or vast—with short runs or long—there are many ways to profit from Surface experience in mechanizing heat treat equipment for ferrous and nonferrous metals. All of them give you uniform duplication of results; upgraded labor; reduced unit costs; expanded capacity; and strengthened competitive position

You may require a single batch type furnace, (right above) in which work is handled automatically from charge to discharge. For expanded facilities, a battery of such furnaces can be handled by one operator. Standard furnaces can also be linked in sequence to form an automatic heat treat line.

You might want your furnaces integrated directly with machines at separate points in your production line, (right center). This line processes bearing races from raw stock through a sequence of manufacturing operations—machining, heat treating, and finishing.

Your methods may call for a self-contained automatic heat treat line within your production line, (right below). Hoppers convert variable production from machining operations to the steady rate best for efficient heat treating. All operations are interlocked and continuous.

These are merely samples of the range and depth of mechanization know-how which Surface has accumulated since as far back as 1929. That was the date of installation of a completely automatic line for normalizing, hardening, and tempering transmission parts. Still operating, that line has paid for itself many times over.

Explore these advantages for your own operation; write for Bulletin SC-176.

Surface Combustion Corporation, 2377 Dorr St., Toledo 1, Ohio. In Canada: Surface Industrial Furnaces, Ltd., Toronto, Ontario.

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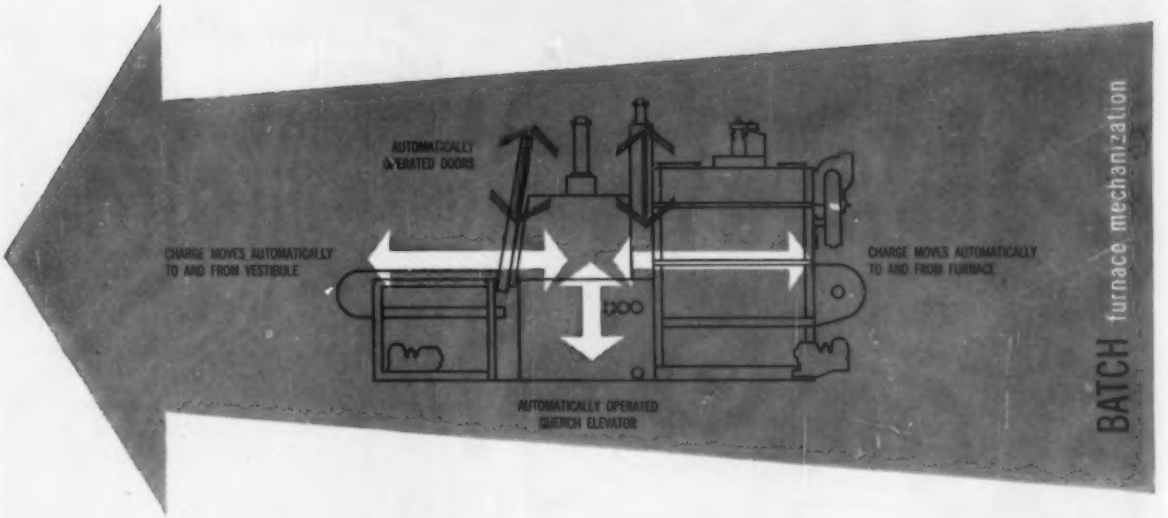
wherever heat is used in industry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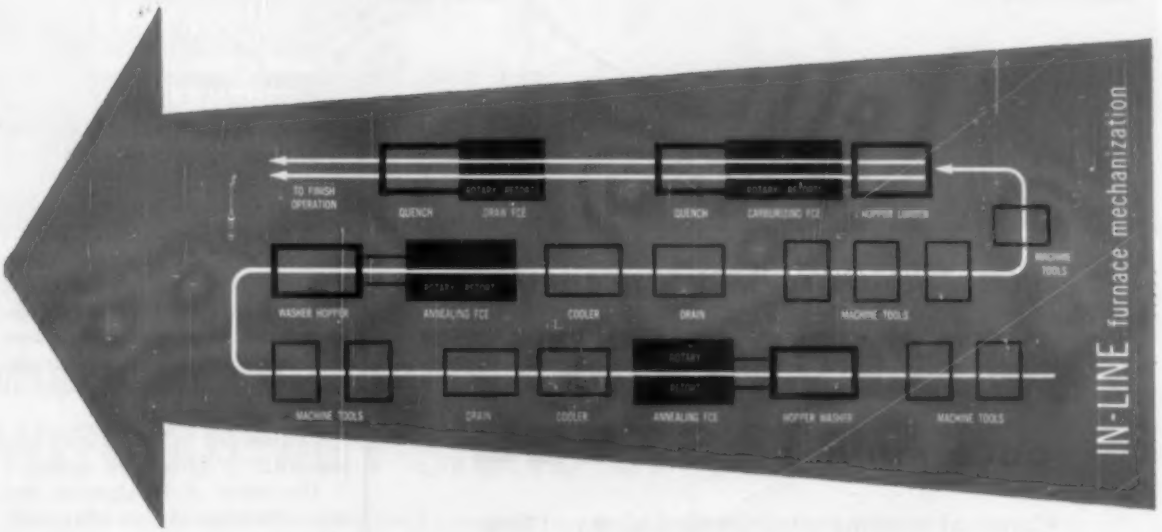
TO FINISH OPERATION
QUENCH
DRAW FCE
QUENCH
CARBURIZING FCE
HOPPER LOADER
MACHINE TOOLS
WASHER HOPPER
ANNEALING FCE
COOLER
DRAIN
MACHINE TOOLS
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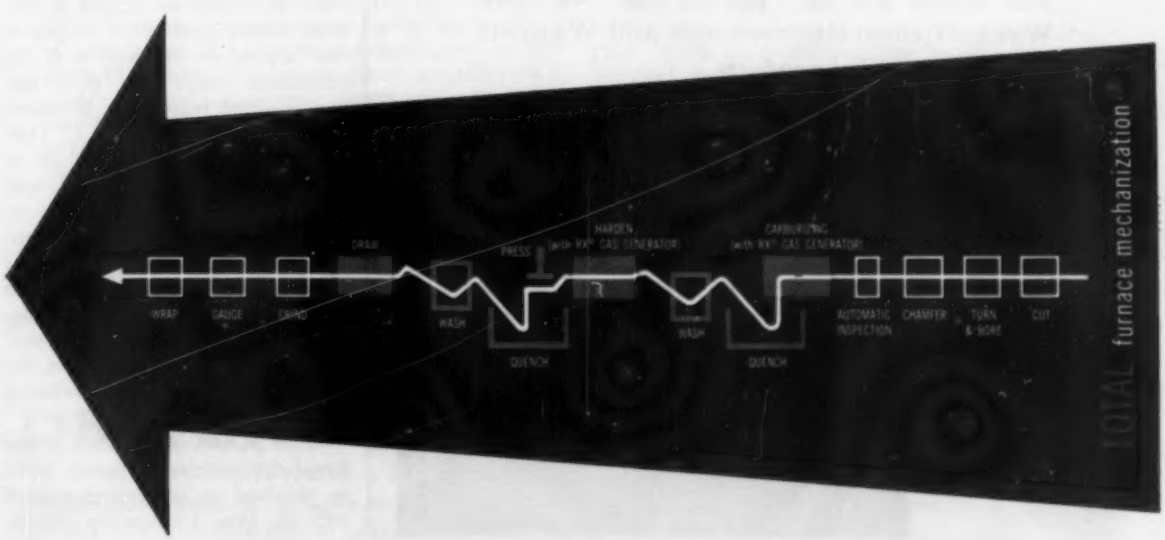
DRAIN
COOLER
ANNEALING FCE
HOPPER WASHER
MACHINE TOOLS
IN-LINE furnace mechanization


DRAIN
PRESS
HARDEN
CARBURIZING
WRAP
GAUGE
WASH
WASH
AUTOMATIC INSPECTION
CHAMFER
TURN & HONE
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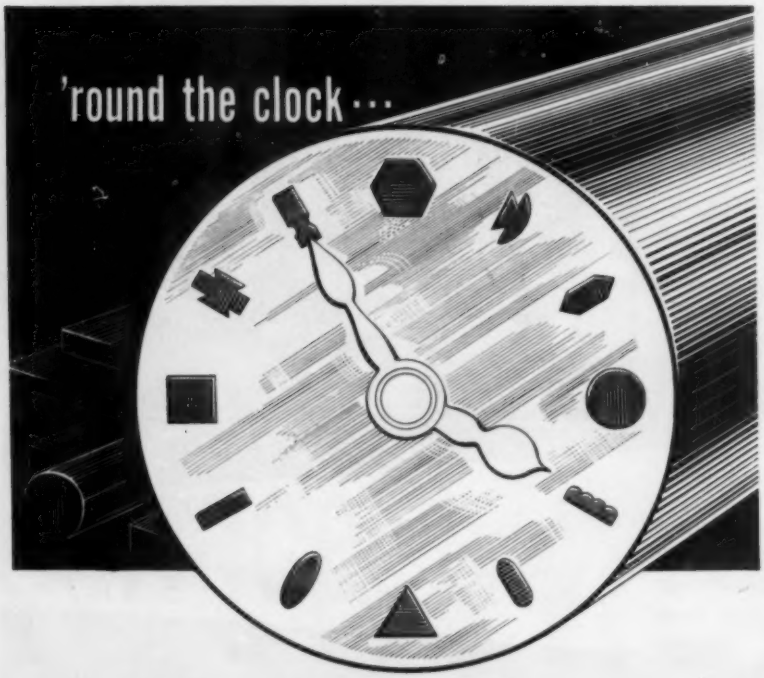
QUENCH
QUENCH
TOTAL furnace mechanization



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Bonding Magnesium . . .

the bonds was very low, the failure occuring cohesively in the chromate coating. Also, there was evidence of blistering within the glue line, an indication of trapped volatile or reaction products.

The hot alkaline chromate treatment used at Avro is covered by specification P-1-1 and is based on British specification DTD 911; it differs from Dow 8 in that pretreatment is effected with sodium hydroxide instead of hydrofluoric acid. The sequence of operations is:

1. Degrease with trichlorethylene vapor.
2. Immerse in boiling 2 to 3% caustic soda for 10 min.
3. Rinse in cold water.
4. Immerse in chromic nitrate stripper solution at 70 to 90° F. for 3 to 5 min. Solution consists of 15 to 20% chromic acid, 2.5 to 3.5% sodium nitrate in demineralized water.
5. Rinse in cold running water; transfer rapidly.
6. Immerse in boiling chromate bath solution for 30 min. (2 to 3 min. for M-1-7 ZE 41 alloys). Solution consists of 3.0% ammonium sulphate by weight, 1.5% ammonium dichromate by weight, 1.5% sodium or potassium dichromate by weight, 0.27% ammonium (0.880 sp. gr.) by volume, and tap water.
7. Rinse in warm water (not above 120° F.), then dry rapidly.

The failure of the chromate film was investigated simultaneously along two paths. In order to overcome the blistering caused by the condensation products, a subprimer was applied to the surface of the chromated magnesium and thoroughly dried before the Metlbond primer was applied over it. Then primers of zinc chromate made to specification MIL-P-6889 and thinned 1 to 9 with Toluol, an Epon-base clear enamel, and regular Metlbond, diluted for better wetting and penetration, were each applied over the subprimer coating. None of these treatments showed any marked improvement over the normal precuring of the Metlbond primer.

In the parallel investigation it was found that satisfactory bonds could be obtained on surfaces pretreated with the Dow 1 temporary chrome

NICHROME* HEARTH PASSES 12,060 HOUR mark in commercial heat-treating service WITHOUT ANY SIGNS OF WEAR!

It is in commercial plants that heat treating equipment is subjected to some of the severest endurance tests. A typical example is the AGF† 166 CE Nichrome Hearth, Shaker Furnace in the Mathews Heat Treating Co. in Newark, N. J. The furnace has been on the job since 1950; its Nichrome hearth casting since July 1954.

The variety of operating conditions imposed on this furnace is typical of commercial use. Atmospheres vary from dry gas cyaniding to straight hardening using combinations of anhydrous ammonia, propane and city gas. Work charges of an endless variety are put through in loads up to 400 pounds an hour and temperatures ranging from 1200°F to 1750°F according to the job requirements. To top it off, the furnace is shut down every night, fired up from cold start every morning and has been kept on a 12 hour per day, 5 day week schedule since July 21, 1954, over 3½ years. Yet the Nichrome hearth shows no signs of wear. Its heat-hour cost record has been satisfyingly low.

"Most important factor in the excellent low heat-hour cost record of this furnace", Jim Mathews reports, "is the use of the Nichrome hearth which has outlasted all the substitute alloys we tried prior to 1954. True the first cost of Nichrome is somewhat higher, but it is actually the cheapest in the long run because it pays off in long operating life. In fact, we now also use Nichrome pots in our salt bath case hardening operations for the same reason".

Take a lesson from the industry which watches costs with a sharp pencil — to keep your heat-hour costs down to the very minimum specify Nichrome, and to get the benefit of priceless engineering experience without obligation, consult with us. We'll be glad to help you.

†American Gas Furnace Co., Elizabeth, N. J.
*TM Reg. U. S. Pat. Office

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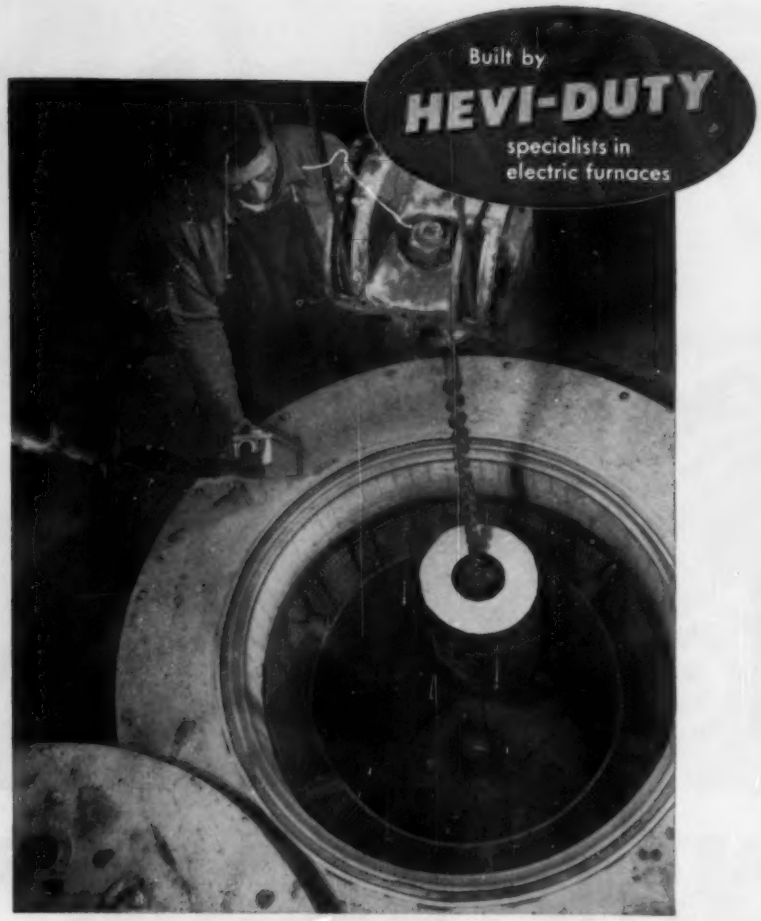


Allegheny Ludlum Chose This Pit Furnace ...for top-to-bottom temperature uniformity

Allegheny Ludlum Corporation, Los Angeles, uses this electric pit-type furnace to obtain uniform hardness along the entire length of 42-inch extruding liners and rams. Uniformity over so great an area calls for unusually good furnace performance. That's why they chose a Hevi-Duty furnace.

A temperature check, made at 18 different stations within the furnace, soon confirmed the wisdom of their choice. It revealed a maximum temperature variation of only plus or minus 5°F. Control like this has virtually eliminated rejects and demonstrated once again that *it takes quality to make quality.*

Write for Bulletin 451 for complete details.

- Heat Processing Furnaces
- Dry Type Transformers
- Constant Current Regulators

HEVI-DUTY ELECTRIC CO.
Milwaukee 1, Wisconsin

Bonding Magnesium . . .

pickle. Shear values averaged 2600 psi. and peel strengths were of the order of 40 lb. Subsequent hot alkaline chromate treatment to specification P-1-1 applied over the bonded specimens did not adversely affect the bond strengths; however the double treatment was unattractive since it added another step to the process and required additional processing tanks.

Variation of the immersion time in the hot alkaline bath did have a pronounced effect on the bond strength, both in shear and in tension (peel). Tensile shear stress showed a gradual loss in strength, and the peel strength showed a rapid loss in strength, with increased time. With immersion times of 2 to 3 min., good bonds were obtained with continuous uniform films. Photomicrographs of sections through the chromate film-magnesium interface and photomicrographs of the surfaces of the chromate films revealed that during the first stage of the treatment a thin light gray crystalline coating was formed, which was tightly adherent and finely crazed. With increased time, these fine cracks were enlarged by the growth of a darker, amorphous material, which forced small fragments of the original coating to the outer surface. After 30 min. the coating had the appearance of a rough conglomerate of minute gray slabs embedded in the softer dark material. With ZE 41, this light gray coating was formed in the first 5 min. of the treatment.

Corrosion tests, applying 20% sodium chloride to chromate-treated and primed panels, resulted in good corrosion resistance for coatings applied in 2, 5 or 30 min.

Even in the best of the bonds, pitting could be seen on the glue line as though some volatiles had been trapped. A further refinement of the curing cycle (varying temperature and time) did not improve this condition. Not until the condensation products were allowed to escape during the initial curing was an improvement made. This was accomplished by applying a vacuum to the curing components up to 250° F., holding at that temperature for a short time, and then increasing the

pressure and temperature to complete the cure. Porosity at the glue line disappeared. With this appoach, the strengths for tensile and peel specimens cut from panels were 3000 psi. and 50 lb.

Further work on this curing cycle revealed that the time required to reach the 250° F. temperature was very important. Too fast a heating rate did not allow the volatiles to escape, resulting in low bond strength, and with a prolonged heat up, a partial cure was effected before the final pressure was applied, and an excessively heavy glue line was obtained. The optimum time to reach a temperature of 250° F. was between 15 and 30 min.

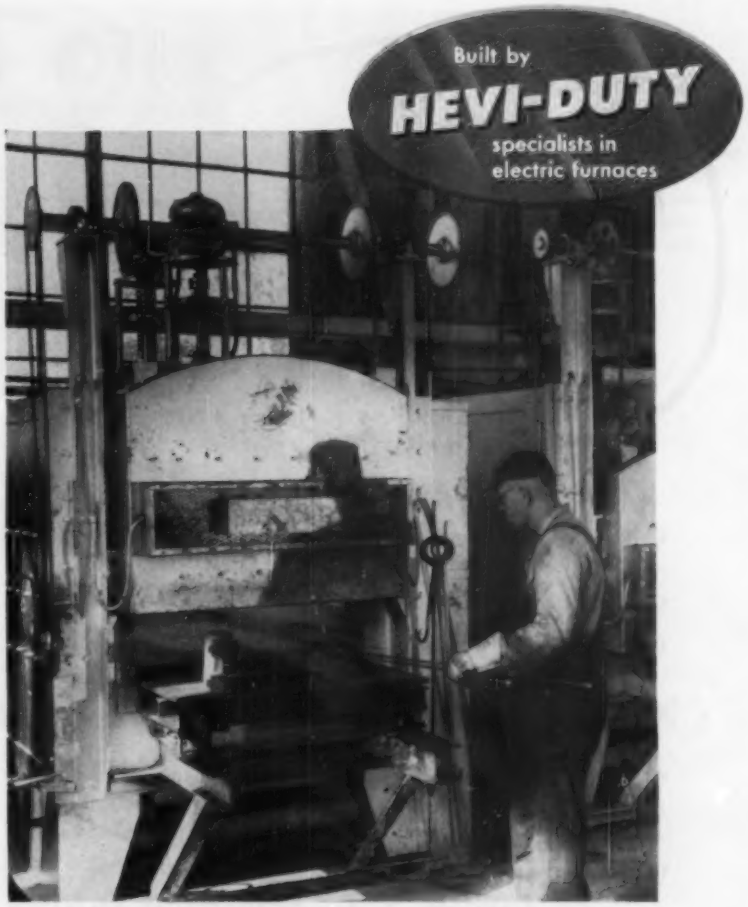
After establishing the curing cycle, the effect of pH in the hot chromating tank on the resultant bond strengths was determined. A pH of from 5.7 to 5.9 was found to give consistent good bonds.

The Complete Process

After insuring that all dimensions are correct and that the degree of flatness of curvatures is such that a good fit can be obtained at the adhesive line with no more than light finger pressure, components are suspended from a rack into a vapor degreasing tank containing trichlorethylene. Degreasing is followed by immersion in a boiling solution of 2 to 3% caustic soda for 10 min. Components are washed in cold water, then dipped in a chromic nitrate stripper solution. After the parts show a uniform silveriness (in 3 to 5 min.), they receive the 2 to 3-min. hot alkaline chromate treatment. All components remain on the racks during the surface treatment prior to priming. They are then taken to the bonding shop where they receive the priming coat within 1 hr. After the degreasing (and until they are finally cured), components are not touched by bare hands; the operators wear lint-free cotton gloves.

Priming the Chromated Magnesium — A thin uniform coating of Metlbond 4021 Type 11 adhesive is applied to the faying surfaces and allowed to air dry for 20 min. Components are then baked in an air circulating oven at 300° F. for 10 min. This is followed by a second coating of the adhesive film which is again precured in an air circulating oven at 300° F. for 1 hr.

(*Continued on p.* 138)



Byron Jackson Division, Borg-Warner Corporation, hardens and tempers high-strength components for oil well tools in this Hevi-Duty box furnace

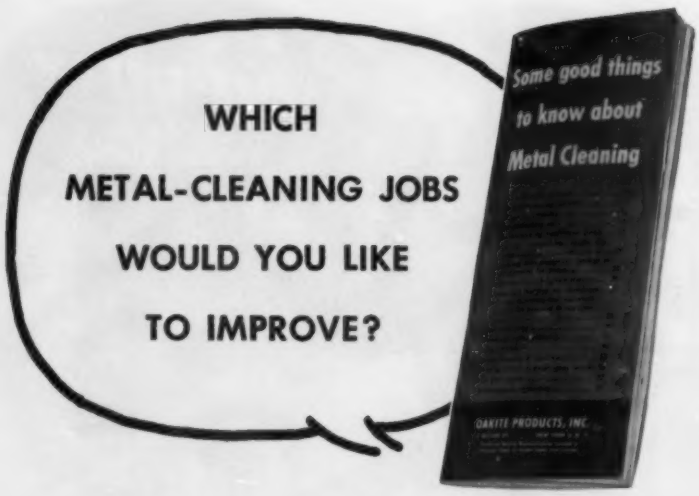
Steel parts processed by Byron Jackson, Los Angeles, face unusually tough tests. They are used in oil well tools where every additional foot of depth adds still further to the weight, strain and torsional stress. In one instance, this equipment drilled to a depth of 23,000 feet — the greatest depth ever attained to date.

Byron Jackson found that components both hardened and drawn in the Hevi-Duty Multi-Range furnace provided maximum high strength characteristics. The wide temperature range combined with precise, uniform control make this furnace ideal for both operations.

Write for Bulletin 341 for complete information on Hevi-Duty Multi-Range Box Furnaces.

- Heat Processing Furnaces
- Dry Type Transformers
- Constant Current Regulators

HEVI-DUTY ELECTRIC CO.
Milwaukee 1, Wisconsin



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¶ Do you need room-temperature cleaning combined in one operation with temporary rustproofing? *See pages 12 and 14.*

¶ Do you know the advantages of alkaline pickling? *See page 21.*

¶ Have you compared the values of iron phosphate coating and zinc phosphate coating in preparation for painting? *See pages 22 and 25.*

¶ Can you use a cleaner that removes rust and oil at the same time; often eliminating all need for pickling? *See page 30.*

¶ Do you have trouble stripping epoxy resins, pigment residues, phosphate coatings and under-paint rust? *See page 31.*

¶ How do you clean parts that are too large to be soaked in tanks or sprayed in machines? *See page 31.*

¶ Are you getting full profit out of your finishing barrels? *See page 32.*

¶ What do you do when oversprayed paint neither floats nor sinks in your paint spray booth wash water? *See page 35.*

¶ Do you need better protection against rusting in process or in storage? *See page 37.*

FREE For your copy of *"Some good things to know about Metal Cleaning"* write to Oakite Products, Inc., 26H Rector Street, New York 6, N. Y.

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Bonding Magnesium . . .

The Autoclave Curing Cycle – The adhesive film is tailored to fit the components and a few cherry rivets are used to insure no movement of the components during bonding. Thermocouples are attached to the parts to record cure temperature at the joint. The assembled components are wrapped in canvas and inserted into a polyvinyl-alcohol plastic bag fitted with felt as a vacuum bleeder. The bag is exhausted by vacuum pump and checked for leaks and then rolled into the autoclave. With vacuum pressure only on the assembled components, the temperature is raised

Four Batches a Day are Produced in This Production Autoclave

to 250° F. and held for 10 min. Under vacuum conditions inside the bag, condensation products are exhausted from the area of the joints. As well, the plastic bag prevents the outside pressure from getting between the parts being bonded and cancelling the clamp-type action of the air pressure. Pressure is increased to 100 psi. and temperature is raised to 300° F. and held for 1½ hr. (pressure cooking). Finally, the temperature is reduced to 140° F., the pressure is released, and the completely bonded parts are removed.

Inspection – With every batch of components, two 1-ft. square panels are included. These completely processed panels are then cut into 1-in. wide strips which are then tested for peel and tensile strength. Tensile strength must average at least 2000 psi. with no value less than 1500 psi. Peel strength must not be less than 40 lb. With this process, Avro Aircraft now obtains strength greatly in excess of the maximum requirements. D.F.R.

LOW COSTS. USS "T-1" Steel's high yield strength (90,000 psi minimum) and ready weldability combined to reduce weight and keep fabrication costs low.

The trailer frame they couldn't tear apart

— built 25% lighter with USS "T-1" Steel

The first big low-bed machinery hauling trailer built by Timpte Bros., Denver, Colorado was made completely from welded USS "T-1" Steel. They sold it to a large construction firm . . . urged the company to *try to tear it apart.*

That was three years ago . . . and according to Mr. R. R. Ruland, Vice President and General Manager of Timpte Bros., the trailer is still in use. It withstood every test of lugging huge loads over rough, back-country roads.

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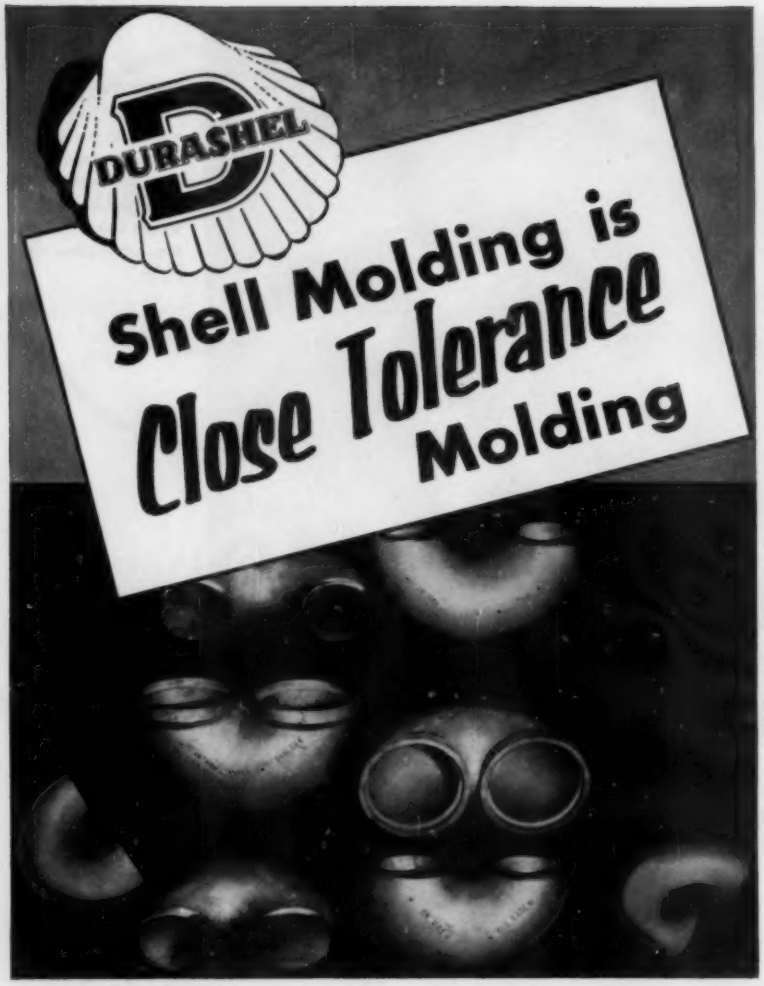
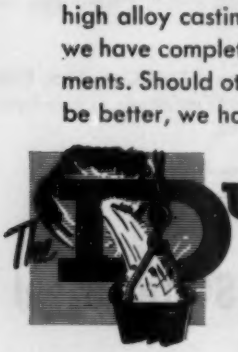


These are Duraloy Shell Molded 180° Bends. And incidentally, several different alloying combinations of chrome iron and nickel are represented in these bends.

One of the outstanding values in shell molded castings is the higher precision or close tolerance casting . . . also usually less machining and finishing . . . than when pieces are cast statically. For quantity production it is usually more economical.

We suggest that you investigate shell molding for your high alloy casting requirements. It has much to offer and we have complete facilities for taking care of your requirements. Should other casting methods—static or centrifugal be better, we have these facilities, too.



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British Nuclear Energy Developments

Digest of "Technical Developments in the Field of Nuclear Energy", by Sir John Cockroft, presented at a meeting of the Dutch Engineering Society, February 1957. Preprinted by U. K. Atomic Energy Authority.

THE DEVELOPMENT of nuclear energy for the generation of large-scale electric power reached an important stage when the United Kingdom Calder Hall nuclear power station was commissioned in May 1956. This reactor consists of a core of 1200 tons of graphite blocks, contained in a pressure drum about 40 ft. in diameter. In channels between the graphite blocks, 10,000 uranium fuel elements, 4 ft. long and 1.15 in. in diameter, are stacked, one above the other. These are sheathed in an aluminum alloy having transverse fins for heat dissipation.

Technical developments which made Calder Hall nuclear power plant possible were:

1. Production of graphite having a cross section of less than 4 millibarns, procured by careful selection and control of raw materials.

2. A change from aluminum to magnesium canning, furnishing a lower cross-section material, usable at temperatures 100° higher.

3. An improvement in uranium fabrication and heat treatment techniques to reduce growth or distortion on thermal cycling or under irradiation, achieved by the production of small randomly orientated grains by heat treatment in the beta phase.

4. A detailed study of the reaction between carbon dioxide and graphite as a function of temperature and irradiation.

5. The alteration from longitudinal to transverse finning to improve the heat transfer characteristics.

Other important innovations pertained to (*a*) determining optimum lattice parameters, over-all reactivity, and the control system; (*b*) welding the 2-in. thick, 47-ft. pressure vessel in place, and stress-relieving it to a dull red heat, with strain gages as indicators; and (*c*) installation of detectors for fuel element failures.

Dr. Cottrell, working on solid-state physics, predicted that fission

(*Continued on p.* 144)

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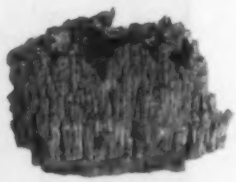

TO THE REACTOR DESIGNER: This new development in zirconium supply means that the superior and versatile qualities of this metal are available *now* for incorporation in the design of all types of nuclear reactors.

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Nuclear Energy . . .

fragments in uranium metal would increase its creep rate a hundredfold at a temperature of 100° C. (212° F.). He checked this by irradiating loaded uranium springs in BEPO, a graphite-moderated natural-uranium pile, and noted the extension. Thence, it was predicted that the bowing of the lowest, coolest fuel elements of the Calder reactor would bear the weight of all those stacked above them, and would be substantially augmented by radiation. This theory was largely borne out in practice. In future reactor designs, however, each fuel element will be supported individually from the graphite, to restrict bowing.

At the far end of the development scale was the fast breeder reactor: British experiments with the zero energy fast reactors fueled by plutonium and uranium-235 were very favorable since they resulted in good breeding gains in the plutonium-uranium-238 system. The next logical step was to build an experimental reactor (Dounreay) which would not only produce more fuel than it burned, but would also generate power.

The Dounreay reactor has a relatively small core – about 24 in. in diameter – composed of uranium-235 fuel elements. The heat is removed by liquid sodium. The reactor contains a series of 12 heat exchangers with a secondary heat exchanger circuit. The core has a heat rating approximately 12 times greater than that of Calder Hall, and 10 times that of the most highly rated boiler. Thus, metallurgical engineers have had to study carefully problems associated with expansion and distortion of the core, and its impact on reactivity. Irradiation damage, due to high-intensity fast-neutron flux – of the order of 10^{15} neutrons per sq.cm. per sec. – is the limiting factor in burn-up, and determines the number of times the fuel will have to be processed in its lifetime.

Cheap processing and long burn-up are essential for the economic operation of fast breeder reactors. A number of safety problems also must be solved before it will be suitable for universal application.

V. S. SWAMINATHAN

STRAITS TIN REPORT

New developments in the production, marketing and uses of tin

MALAYAN TIN BUREAU

A new engine bearing alloy of tin (about 20%) and aluminum was recently perfected after more than 3 years of testing. Of meshed tin-aluminum, in which the tin forms a lacework within the aluminum, the alloy gives a better balance between high fatigue resistance and low rate of wear than any other standard bearing known. It is also cheaper to manufacture than ordinary copper-lead plated types.

* * *

In his address to the Legislative Council in December, His Majesty the Yang di-Pertuan Agong again stated that the policy of his government will be to assist the tin and rubber industries, upon which the economy of the Federation of Malaya largely depends. "My government realizes it cannot maintain or increase the prosperity of the country unless it renders every assistance possible to both these industries," he said.

A new alloy of tin (13%), aluminum and titanium shows very good high-temperature characteristics. It is now being used in Europe for turbine parts in aircraft engines.

Glass and plastics can now be successfully "tinned" with either solder or a fusible alloy. It is done by applying the metal from the surface of a small grinding wheel, which presses it into the ground surface.

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Dept. 25E, 1028 Connecticut Ave., Washington 6, D.C.

High-Phosphorus Pig Iron Refined With Lime and Oxygen

Digest of "Oxygen Lime Powder Injection — A New Steelmaking Process", by B. Trentini and M. Allard. This paper was presented at the 15th annual A.I.M.E. Electric Furnace Steel Conference, February 1958.

IT IS NOW POSSIBLE to produce steel from high-phosphorus pig iron by the basic oxygen process. When lime powder is injected along with the oxygen blast, the phosphorus is fluxed away, and steel fully equivalent to that produced in the open-hearth results.

The process, developed by the Institut de Recherches de la Sidérurgie (IRSID), was first tried in small-scale tests of 660 lb. and 3 tons; heats of 20 to 30 tons were soon being produced. The small-scale charges were held in vessels with linings of rammed dolomite. For the larger charges, a basic converter with a tight bottom of rammed dolomite was employed; the lining consisted of pressed dolomite bricks.

The lance was water cooled, the end being located about 3 ft. above the bath level. Figure 1 shows the converter during preheating.) Powdered lime distributors permitted the injection of all the lime needed for refining. Pig irons with 1.8%

Fig. 1 — View of Vessel for 20-Ton Heats During Preheating. Note oxygen lance in foreground

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Oxygen-Lime Process . . .

P required an average of 330 lb. of lime per ton, while those with 0.2% P needed about 150 lb. per ton. The lime used was of industrial quality and came from the steel plant bins. Charged to a hammer mill turning at high speed, a powder finer than 2 mm. was produced.

A virtually pure oxygen (99.5%) was supplied by a central plant under a pressure of 210 psi. Cooling additions consisted of either scrap or rich iron ores which contained about 55 to 57% iron, 1 to 2% lime, and 10 to 12% silica. The greater part of the following technical data refer to pig iron with a high phosphorus content; however, low-phosphorus irons have also been readily treated.

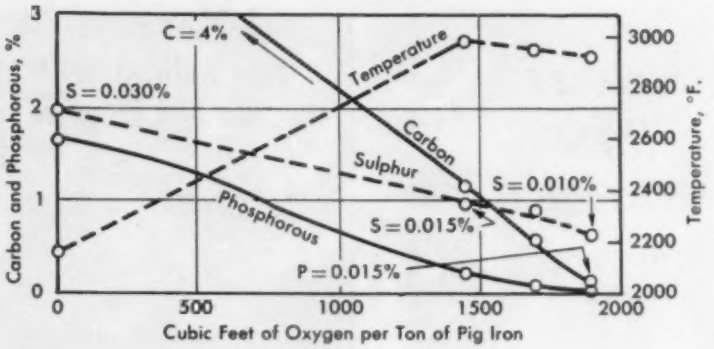

Fig. 2 – Changes in Carbon, Phosphorus, and Sulphur During Oxygen Blow. The temperature rise is also shown

The refining of high-phosphorus pig iron is divided into several steps. After pouring the pig iron into the vessel, it is tipped up to permit lowering of the lance and admission of oxygen and powdered lime. During the first phase, about two-thirds of the oxygen and powdered lime necessary for the complete refining are blown in. Ore or scrap is also added, depending upon the composition and temperature of the iron. At the end of this stage, the bath should be about 2900 to 3000° F. for a basic slag low in iron oxide. That slag, which is not foamy, is then poured out in part.

The blowing of oxygen and lime is started again, with an addition of ore or scrap, determined by the temperature during the first phase. At the end of this second phase, the metallic bath, which is around 2900° F., contains about 0.5% C and less than 0.1% P. Again the bath is partly slagged off.

For the last phase, the blowing of oxygen and powdered lime is continued until extra low-carbon steel is obtained.

A ton of pig iron with 3.8% C, 0.5% Si and 1.8% P consumes about 330 lb. of lime and 2000 cu.ft. of oxygen during the blow. With the present supply of oxygen, blowing time for a 20-ton heat is 20 to 30 min.; time from charge to tap is a little less than 1 hr. As production reaches routine status, this time will undoubtedly be lessened. Figure 2 illustrates the chemical and thermal changes which occur in the refining of a typical 20-ton heat.

Generally, low-carbon rimming

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ACP ALODINE* — its properties and functions in protecting aluminum alloys and bonding paint to them

By ALFRED DOUTY: Technical Director, AMERICAN CHEMICAL PAINT COMPANY

Aluminum protects itself against corrosion by a coating of its own oxide. This adds weight, but does not provide complete protection. Even commercially pure aluminum in clean air at ordinary room temperature oxidizes indefinitely.

The use of adherent inorganic protective coatings on aluminum has long been recognized as efficacious in reducing corrosion rate and prolonging paint life. Since aluminum oxide tends to be protective, it is natural that the most intensive early efforts in this direction should have involved processes for improving the properties of the naturally occurring oxide coating. Anodizing, or electrochemical oxidation, although it is one of the most effective of such methods, is rather costly and time consuming.

ALODINE†

Early in 1945 a new chemical process was devised for producing an amorphous phosphate coating on aluminum. Its simplicity, speed and economy and the unique properties of the coating have resulted in wide commercial acceptance. It is called the Alodine Process.

Some idea of the effectiveness of the Alodine coating on unpainted 3S Grade aluminum may be had from Fig. 1. All panels were removed from the salt spray cabinet after 300 hr. except the Alodized and anodized panels, which were continued to 800 hr.

Organic protective and decorative coatings, such as paint, likewise require a corrosion-retarding undercoating of the kind produced by Alodine to achieve their maximum life and adhesion.

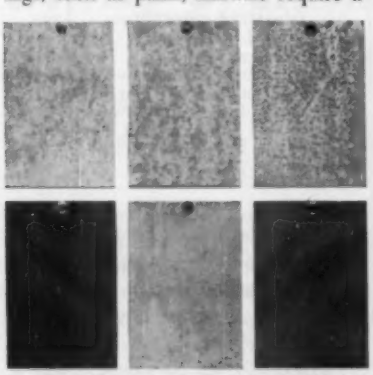

Fig. 1. Salt spray test comparison of Alodine with other surface treatments on unpainted aluminum. (Left to right, top row) solvent wiped —300 hr.; alkali cleaned—300 hr.; phosphate coated—300 hr. (Bottom row) chemically oxidized—300 hr.; anodically oxidized—800 hr.; Alodized—800 hr.

The effect of the Alodine coating in retarding underpaint corrosion is shown in Fig. 2. The Alodized panel was given a top coat only. All other panels in the series were primed after the surface treatments with a regular automotive product, baked, given a surface coat dry-scuffed with sandpaper as per standard automotive practice, and then finished with a regular black baked top coat. The panels were removed from the salt spray after failure of the paint film had set in.

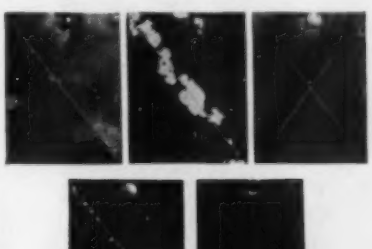

Fig. 2. Salt spray test comparison of Alodine with other surface treatments in retarding underpaint corrosion. (Left to right, top row) alkali cleaned and phosphoric acid dipped—300 hr.; phosphoric acid, solvent cleaned—300 hr.; zinc phosphate coated—400 hr. (Bottom row) anodically oxidized—3000 hr.; Alodized—3000 hr.

COATING CHARACTERISTICS

The coating produced by this new process is an amorphous metallic phosphate, dense, rather hard, and apparently nonporous. Unlike most oxide films, it is nonabsorptive and cannot be dyed or stained. Sealing in hot water or salts has no apparent effect. It differs markedly in appearance from previously known phosphate coatings, as shown in Fig. 3.

Electrical Resistance. Very little information is available at the present time on the electrical properties of the coating, but it is known that resistance increases very rapidly with thickness and as a result coatings normally produced offer extremely high resistance.

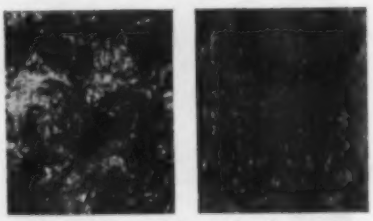

Fig. 3. (Left) conventional phosphate coating on aluminum; (right) Alodine coating produced in 3-min. immersion, rinsed and air dried. Magnification 500 diam.

Weight and thickness. Generally speaking, the weight of the amorphous phosphate coating increases with processing time, bath strength, and bath temperature. It is interesting to note that the increase becomes less and less pronounced as the temperature increases and actually reverses itself into a sharp decline between 130 and 140°F.

Adhesion. The original purpose in development of this process was to improve adhesion of the paint to aluminum surfaces and thus lengthen their overall life. Only later was it discovered that the film itself provides corrosion resistance.

Resistance to Bimetallic Corrosion. Since it has very high surface resistance, the coating, as would be expected, offers good resistance to bimetallic or galvanic corrosion. Test samples are available to illustrate the insulating effects.

We present here a general and by no means complete, report on ACP Alodine—its properties and uses in protecting aluminum alloys. Your ACP sales representative can give you a much fuller story. Or write us at Ambler.

*Alodine is a registered trademark of American Chemical Paint Co.

†Since the introduction of Alodine amorphous phosphate coatings, ACP has developed a complete line of Alodine amorphous chromate coatings for superior corrosion resistance.

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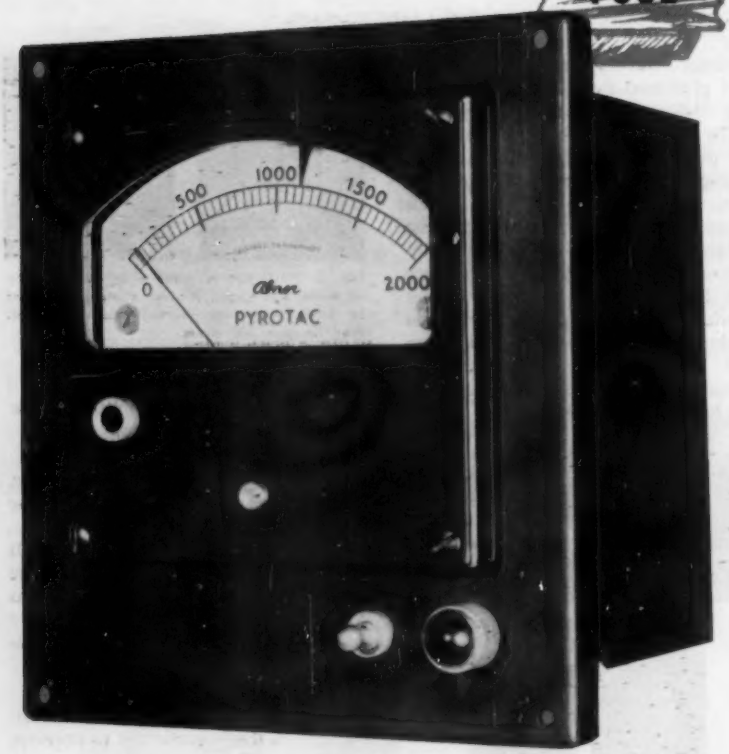

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Oxygen-Lime Process . . .

steels obtained from high-phosphorus pig iron by this method are characterized by their very low phosphorus, sulphur and nitrogen contents. For example, a series of seven 20-ton heats contained 0.04 to 0.07 C, 0.016 to 0.025 P, 0.008 to 0.013 S, and 0.001 to 0.002 Ni. These values show that the steel produced is equivalent to openhearth quality in phosphorus content and is considerably better in sulphur and nitrogen content.

Several other advantages exist. For example, pig irons rich in silicon can be refined without foaming or splashing of slag, less iron oxide is formed (reducing red fumes) and fluxing agents are not needed. The absence of fluxes presents a very appreciable advantage with regard to the life of the lining; the low consumption of dolomite is confirmed by the magnesium oxide contents of the slags, which are about 1% in the intermediate and final slags.

It is also possible to apply the process to pig irons with lower phosphorus contents. The mechanical properties obtained on the material are equivalent to those of a deep drawing openhearth steel. It is felt that this process also compares favorably with the basic openhearth process when production rate, investment costs, and production costs are taken into account.

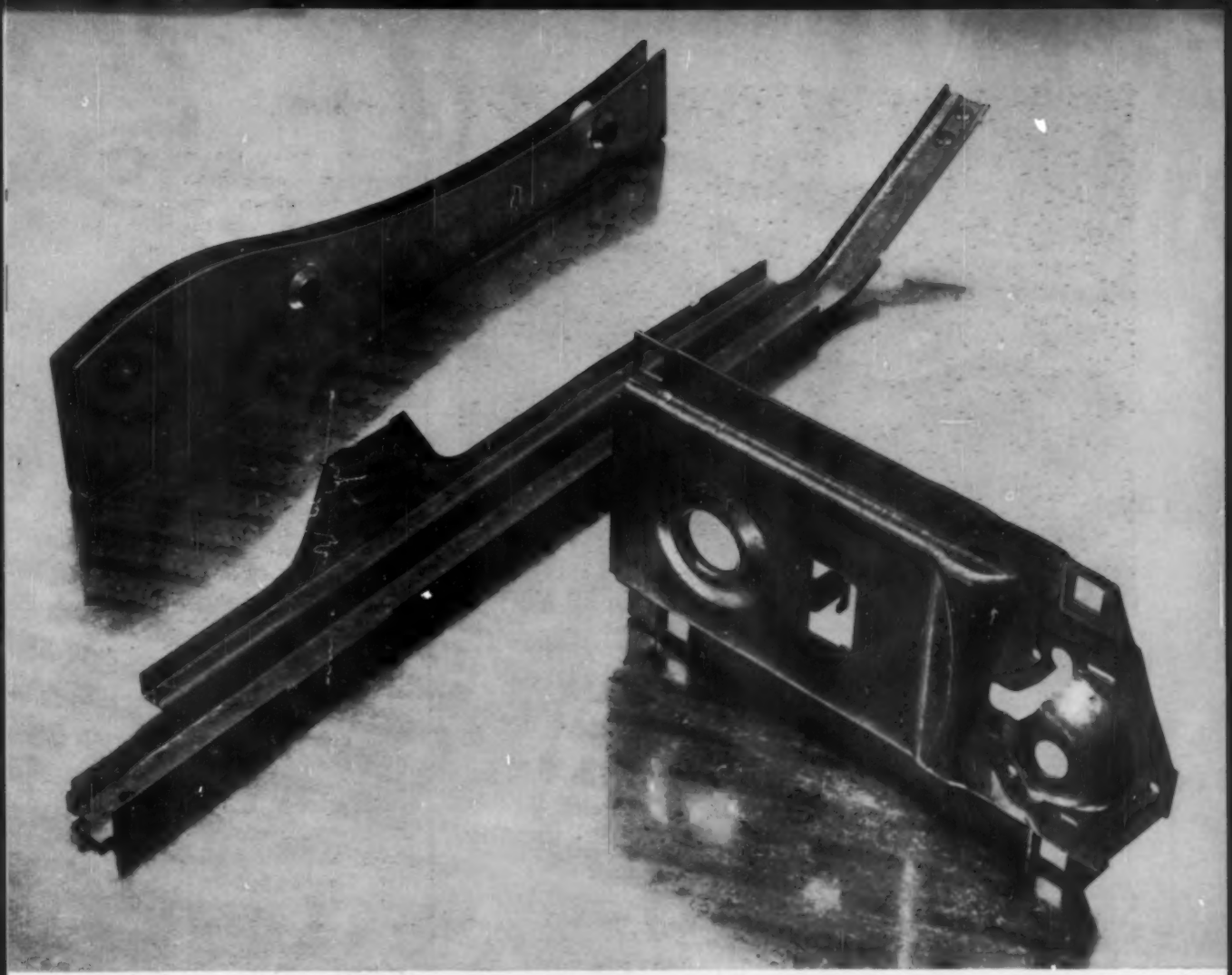
C.R.W.

Outlook for Beryllium

Digest of "Beryllium — Present and Potential Uses", by Lawrence F. Boland. Presented at the Atomic Energy Management Conference, sponsored by Atomic Industrial Forum and National Industrial Conference Board, New York, March 17, 1958. 15 p.

BERYLLIUM owes its recent expansion of production to the growth of atomic energy. Two materials are involved: beryllium metal and beryllium oxide. They complement each other.

Practically all beryllium metal is used as a reflector or moderator in order to capitalize on its low thermal neutron absorption cross section. For example, the new A.E.C. Engineering Test Reactor at Idaho Falls



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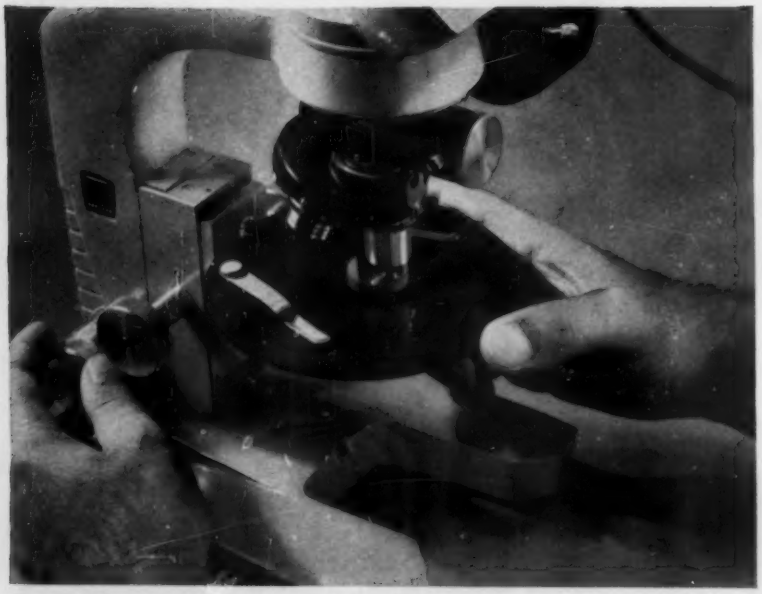

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American Optical Company

INSTRUMENT DIVISION, BUFFALO 15, N. Y.

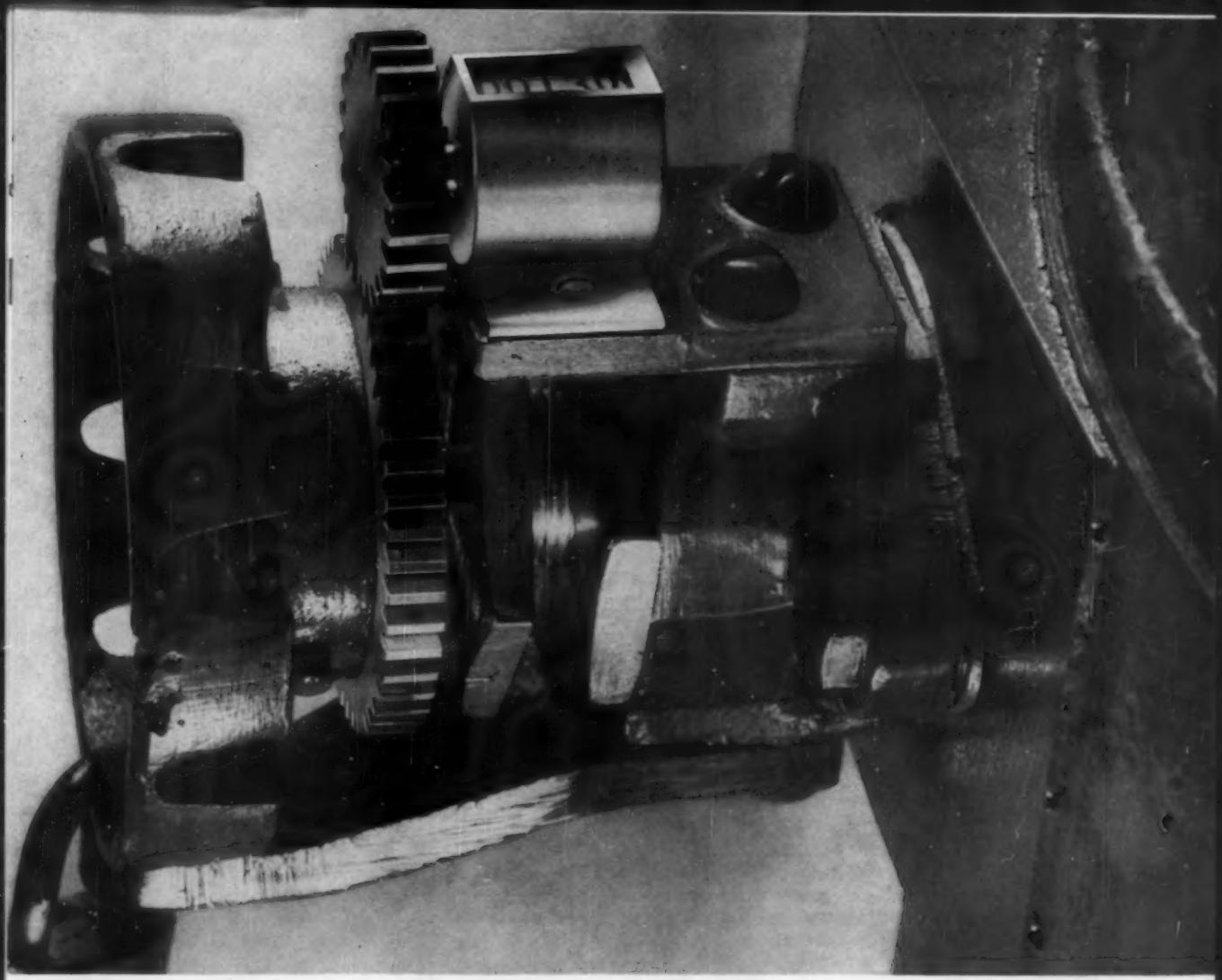
Beryllium . . .

has, surrounding the core of the reactor, an inner reflector of beryllium. Its primary purpose is to reflect neutrons from the chain reaction back into the core, thus reducing the amount of fuel needed and increasing reactor efficiency.

New Uses – In addition to its uses in nuclear reactors and in alloying copper, beryllium is being considered for many other applications. These include parts of X-ray cameras and high-speed cameras, aircraft brake parts, underwater instruments, accelerator targets, as a "getter" material for use in heated liquid metals, gas turbine engine parts, high-frequency electronic parts, aircraft instruments, beryllium additives to aluminum, zinc and other alloy melts to act as an oxidizer, high-velocity testing equipment, beryllium additives to steel and to aluminum baths for coating of steel, rotor shafts in refrigeration equipment and rocket engine components.

The Air Force and the aircraft industry are showing substantial interest in beryllium for structural applications in aircraft, missiles and perhaps space ships. Interest here stems from the fact that beryllium is the only light metal with a high melting point and extremely high modulus of elasticity. Although beryllium is almost as light as magnesium, the modulus of elasticity is one-third greater than that of steel. Currently under way are many research and development programs on beryllium, sponsored by the Air Force. Programs contracted for to date include evaluation of additives to beryllium, brittle-phase investigation and sheet rolling. Further research projects are planned on casting, composite materials, joining and surface effects, as well as programs on development of forging and extrusion alloys.

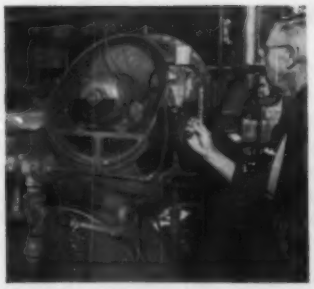
Beryllium Oxide – Indications are that beryllium oxide may rapidly parallel beryllium as a material for construction of atomic reactors. It is a refractory material with rather unique properties. Prime interest at present is in its use as a moderator and/or reflector, chiefly to take advantage of its high melting point (twice that of beryllium metal). Hot pressed and machined shapes of beryllium oxide are now being pro-



Air-gas Ratio Valve

For precise control of furnace atmospheres . . .

Come to Kemp



Twin installation of Model 6-MR Atmos Gas Generators deliver up to 6,000 cfh at Thomas Strip division of Pittsburgh Steel. Increased equipment capacity, reduced labor costs, and closer control make Kemp units money savers in every installation.

For heat treating and annealing metals in inert atmospheres, you can rely on Kemp Atmos or Nitrogen Generators as a dependable source of inert gasses. Kemp generators are built around the patented Kemp Industrial Carburetor, which guarantees a steady supply of exact analysis inerts, regardless of demands on the line. With Kemp units supplying your furnaces, you get greater control . . . a better product at lower cost.

The Kemp Atmos Generator, a rich exothermic gas producer, is suitable for most furnace applications; while for more critical uses the Kemp Nitrogen Producer is recommended. Both are noted for durability and dependability. Rugged Kemp design gives optimum performance for years, with only minimum maintenance and care.

Kemp generators may be engineered as an integral part of new furnace construction, adapted to existing units, or furnished as a separate setup.

Your Kemp Representative, listed in the Chemical Engineering Catalog, will give you complete details. Or write direct for Bulletins I-100 and I-101. The C. M. Kemp Mfg. Co., 405 E. Oliver St., Baltimore 2, Md.

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Kemp Immersion Melting Pots

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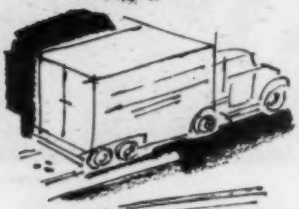

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OFFICES IN PRINCIPAL INDUSTRIAL CITIES

Beryllium . . .

duced commercially to densities as high as 2.85 g. per cc. (about 95% of theoretical) for use in nuclear reactor construction.

Electronic Uses – Unlike most ceramic materials, which are poor heat conductors, beryllium oxide possesses high thermal conductivity. It also possesses good insulating properties for high-frequency electrical currents. These characteristics suggest many applications in electrical and electronic fields. Among applications being considered are Klystron and ceramic tubes, for which low dielectric losses and high thermal shock properties are required. Work is being done on beryllium oxide for power tube components to increase power output of the tubes and reduce the size of cooling units. Beryllium oxide is also being used as a slurry for coating graphite crucibles where carbon contamination is undesirable. It is being studied for use in antenna window applications, airborne radar antennas for electronic parts, high-temperature thermocouples, protection tubes, cooling power transistors in electronic equipment and for guided missile components such as gas seals.

Today, in the electronics industry the trend is towards higher service temperatures. This creates many new problems. Beryllium oxide is radiation stable and has high-temperature characteristics including good thermal shock properties. This should suggest many applications to the electronic-nucleonic engineer.

Shortcomings – An obvious question: Why isn't beryllium now being used in more tonnage by the aircraft industry, in electronics and in other fields? The answer lies in these four limiting factors: cost, availability, brittleness and toxicity.

Though demand has brought the cost of beryllium metal down from the $100 to $150 per lb. for which it sold in the late forties, it is still an expensive metal. Today's prices are around $47 per lb. for billets, $65 to $80 per lb. for hot pressed and rough machined blocks. If the anticipated aircraft uses materialize, however, these prices might be reduced. It has been estimated that if present annual volume holds and an additional 200,000 lb. of beryllium a year were

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Brake Die saves shop time in forming overlap for steel spout

The problem sounded simple enough — putting an overlap in a section of 20-gage stainless steel, which was then formed into a spout for use in meat-packaging tables. But getting a tool steel which could do the job more economically than the grade formerly used was somewhat of a challenge for the manufacturer, J. B. Dove & Sons, Inc., Philadelphia.

The answer was Bethlehem Brake Die, supplied by our local tool steel distributor, Hill-Chase & Co. Because of Brake Die's easy machinability and good wear-resistance, the new die minimized manufacturing costs. It also helped in producing a better-looking product. Said one of the Dove engineers: "We like Brake Die. It's doing a good job for us."

Brake Die, a special alloy steel, is oil-quenched and tempered to develop a fine balance of mechanical properties. It's ideal where wear-resistance, toughness, resistance to impact and good machinability are required.

Typical Analysis

Carbon 0.50	Manganese 0.90
Chromium 1.00	Molybdenum 0.20

Chances are there might be one or more applications in your shop right now where Brake Die steel could be used to good advantage. Why not talk it over with your Bethlehem tool steel distributor?

BETHLEHEM TOOL STEEL ENGINEER SAYS:

How to Shrink-Fit Tool Inserts

Shrink-fitting of tool steel inserts is a procedure which is being widely used to improve the service life of tools. Shrink-fitting is most applicable to rings and cylinders, such as are used in heading and drawing operations where the tools can be shrink-fitted into large retaining rings. The shrink-fit sets up radial compressive stress in the tool, which is available to oppose radial tensile stress set up in service, and thereby improves the performance as compared to solid tools which are not pre-stressed. Shrink-fitting of tools should be carried out as follows:

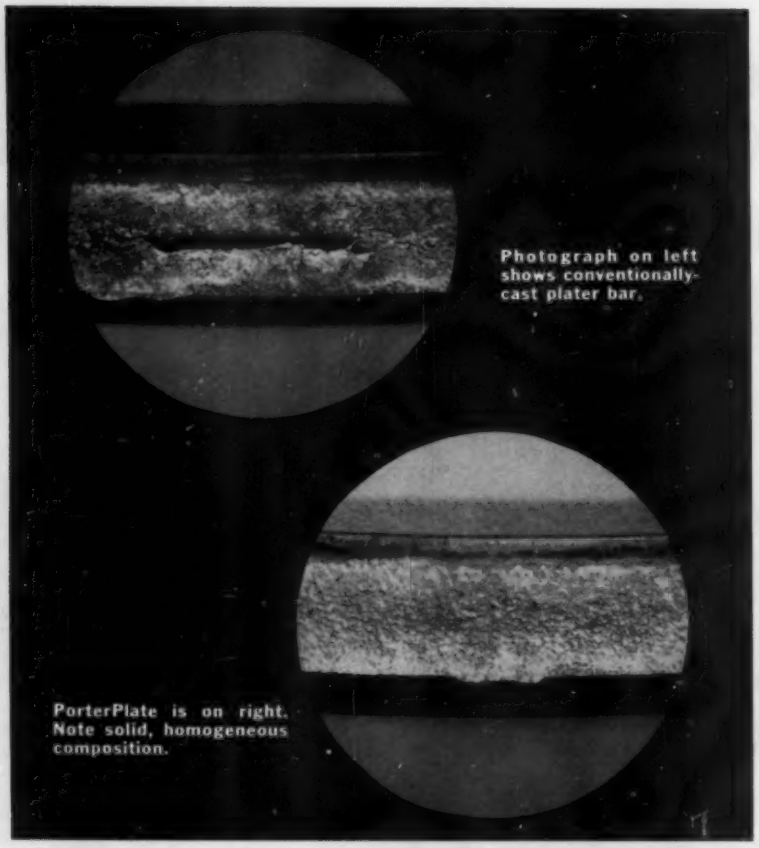
1. The retainer must be of adequate diameter and strength to provide the stresses required on the tool insert. This generally means that an alloy steel capable of hardening to approximately 300/400 BHN must be used. Shock-resisting tool steels heat treated to approximately Rockwell C 48 to 52 are used on heavy duty applications. It is recommended that the OD of the retainer be a minimum of twice the ID (preferably three times the ID).

2. A shrink-fit allowance of .003/.004 in. per in. should be provided for. This means that the OD of the insert is .003/.004 in. per in. larger than the ID of the retainer into which it must fit. These dimensions must be carefully maintained in order to obtain the benefits of shrink-fitting.

3. The OD of the insert and the ID of the retainer should have a smooth finish, preferably produced by grinding.

4. The retainer should be heated to a temperature sufficient to cause the expansion necessary to assemble the insert. Care should be exercised not to exceed the tempering temperature used in heat-treating the retainer. If necessary, the insert may be sub-zero cooled to aid in providing the clearance required for assembly.

5. After assembly of the parts, cooling of the assembly should be rapid enough to prevent over-tempering of the insert by heat transferred from the retainer.



New PorterPlate bars are continuously cast and extruded

GAS HOLES AND BLISTERS ELIMINATED

New techniques have produced a new kind of plater bar—a continuously cast and extruded product called PorterPlate. These new processes have eliminated the gas pockets and blisters that characterize conventionally cast plater bars. Carefully controlled pouring of the molten metal and controlled solidification rates result in a remarkably sound metal of extremely dense, homogeneous composition.

PorterPlate bars are available in all popular base metals, *including* nickel silver. And Riverside-Alloy's long years of experience in plater bars (they were our very first product) assure you of consistent quality and uniformity in every new PorterPlate bar.

We'd like to send you complete details on PorterPlate. Information is free, and yours by writing to *Riverside-Alloy Metal Division, H. K. Porter Company, Inc., Riverside, N. J.*

H. K. PORTER COMPANY, INC.
RIVERSIDE-ALLOY METAL DIVISION

Beryllium . . .

required, the price could be reduced another 15 to 20%.

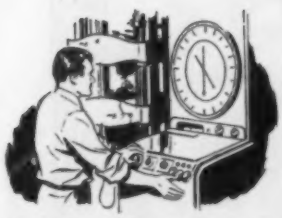
Periodically, when beryllium is reviewed for possible use in new fields, one of the negative features mentioned is its scarcity. The beryllium industry has never been put to a test but it is confident that substantial increases in the supply of beryllium can be found as new uses develop. With regard to production capacity for beryllium metal, two new plants, designed for a minimum of 100,000 lb. per year each, have sufficient capacity to supply all near-future beryllium requirements.

Brittleness – Ways must be found to make beryllium more ductile. Its lack of "three-dimensional" ductility prevents its fabrication by conventional metalworking techniques. The solution to the ductility problem is the primary objective of most of the research work being conducted on beryllium today. However, the picture is not quite as black as it would first appear. Beryllium is already being used for structural parts. The problem of brittleness is one of degree and does not prevent the use of present-grade beryllium in aircraft and missiles. If further research gives methods for producing beryllium metal with greater ductility, larger fields of application will result.

The health hazard associated with improper handling has constituted another barrier to the wider use of beryllium metal and beryllium oxide. There is no question about the toxic problem, but it's not insurmountable. Beryllium can be handled safely with proper controls. Today, many government installations and an increasing number of industrial concerns are fabricating beryllium parts in their plants.

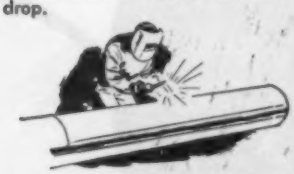
Fabricators Needed – There is a need for additional fabricators of beryllium metal components to supply both nuclear and nonnuclear fields, not only aircraft subcontractors, but also companies whose normal business is forging, precision machining, stamping, manufacturers of fasteners, instrument makers and others. Interest in beryllium as a material is advancing rapidly, and current research will create future demand for sources of beryllium components. A.G.G.

Premium quality extruded steel pressure tubing at standard prices



Transverse Strength, 30% to 50% higher than conventional, withstands higher internal pressures.

Improved Internal Finish offers less resistance to flow — reduces pressure drop.



Fewer and Faster Field Welds, due to close concentricity and uniform wall thickness. 50-foot lengths require fewer joints, reduce welding costs 50-60%.

High performance Chrome-Moly Alloy extruded steel pressure tubing *...in diameters from 14" to 18" o.d...in standard wall thicknesses ...in lengths from 20 to 46 feet...* is now available *from stock* for immediate delivery at standard prices.

Other diameters, of Chrome-Moly and Austenitic Stainless, ranging from 10" to 20" with wall thicknesses ½" to 5¼" and in lengths up to 50 feet, are available on a four-month delivery schedule.

The unusual properties of this extruded tubing, such as exceptionally high transverse strength, impact strength and ductility, make it ideally suited to high-temperature, high pressure applications in the power, petrochemical, food processing and other process industries.

Contact our nearest distributor or district office. Experienced application engineers are available for consultation.

Complete Engineering and Processing Services for: ***Extrusions • Castings Forgings • Machining***

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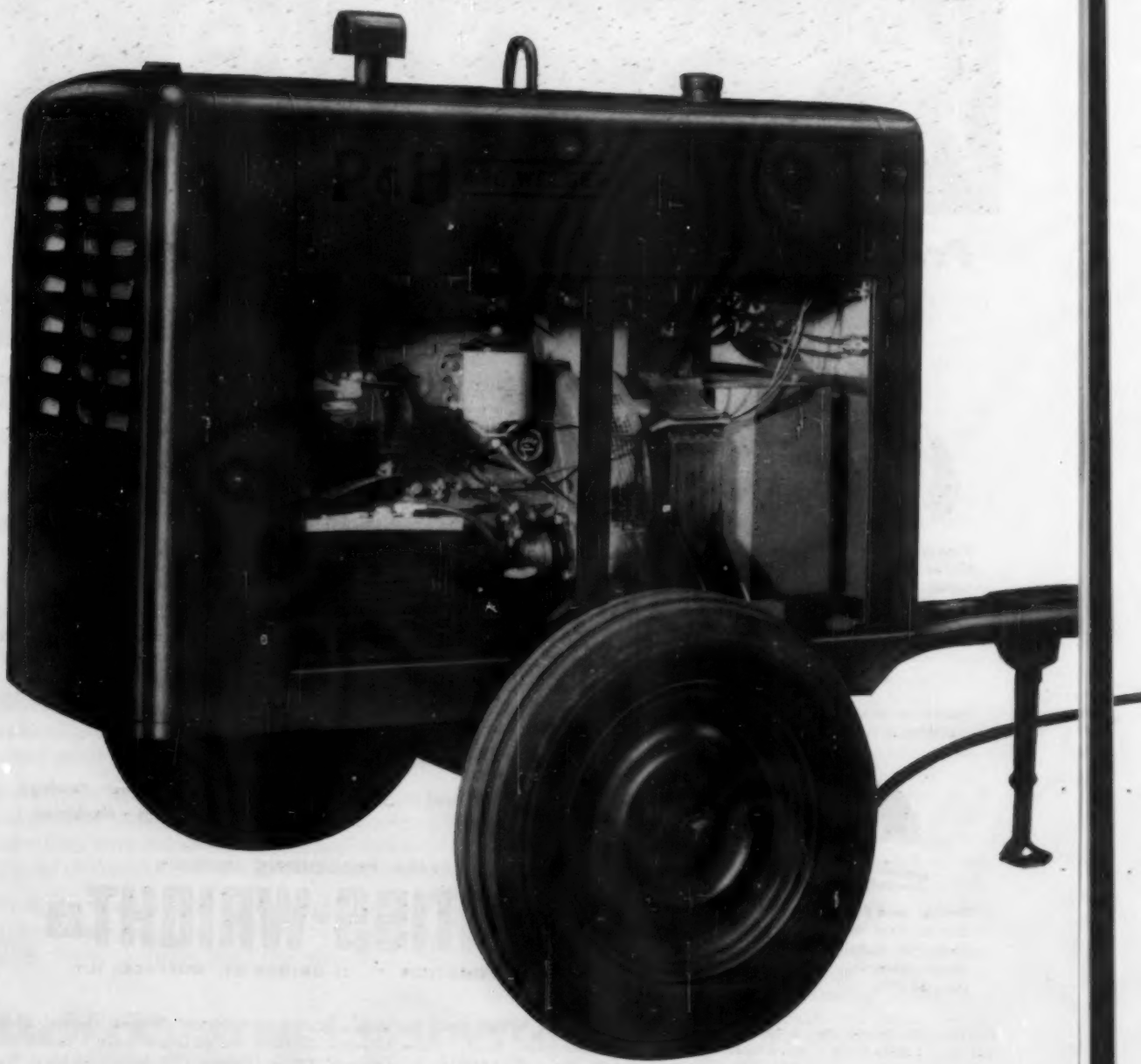
Presenting the NEW P&H ENGINE-DRIVEN for rugged in-the-field welding!



WELDERS

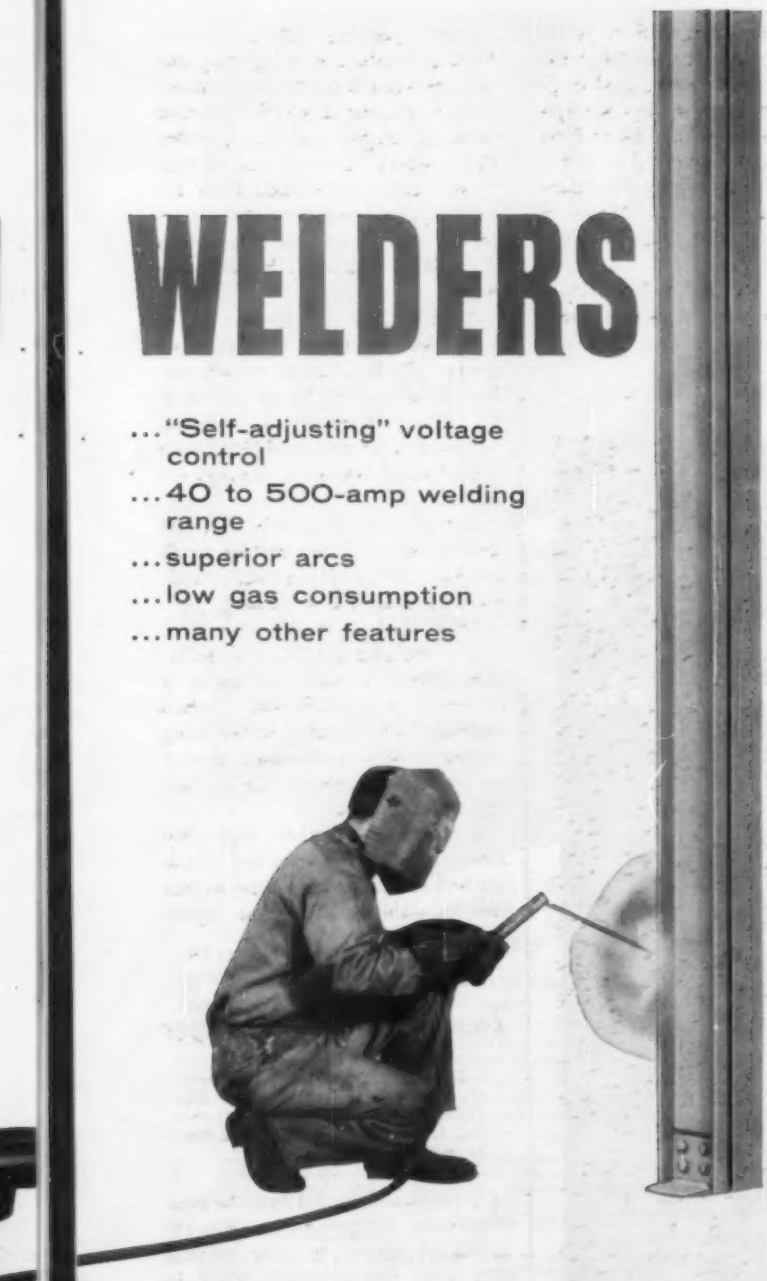
...“Self-adjusting” voltage control

...40 to 500-amp welding range

...superior arcs

...low gas consumption

...many other features



The new P&H engine-driven welders combine rugged, simple design with superior welding characteristics for long-life, low-cost welder operation. Elimination of non-essential parts and easy access to all adjustments simplify operation in the field — assure a self-contained source of dependable power for heavy-construction, pipeline, maintenance, and repair welding. Other benefits include:

- Available in 200, 300, and 400-amp sizes — skid or trailer mounted.
- Stable current — even at extreme ends of range. Limited current peaks allow deep penetration without burn-through.
- Automatic self-adjusting voltage control — dial setting provided for six electrode sizes.
- Easy, accurate current control — exclusive design allows precise settings and resettings.
- Superior arc characteristics—maintain 100% arc stability — instantaneous recovery — prevents popouts.
- Powerful Hercules engine—permits full-shift operation — with gas to spare.
- Dependable idling device — automatically slows engine down to idling speed when not welding. Saves gas and oil, reduces wear.

HARNISCHFEGER

P&H WELDERS • ELECTRODES • POSITIONERS

MILWAUKEE 46, WISCONSIN

Flame Washing in Steel Foundry

Digest of "Flame Washing of Steel Castings", by A. F. Chouinard, *Welding Journal*, Vol. 36, March 1957, p. 219-224.

ACCORDING to the author, removal of riser pads, fins, chill bars, reinforcing nails and core chaplets from steel castings can be accomplished by oxy-acetylene flame washing in one-quarter to one-third the time required by conventional chipping and grinding techniques. Capital investment is said to be as little as one-tenth that involved in grinding, and certain working conditions are improved, such as a reduction in the noise level and reduced vibration fatigue.

Adherence of sand to fins complicates flame washing since insufficient heat is provided to melt the sand without gouging adjacent areas. With a modification – injecting iron powder into the carrier gas – intense heat is generated by the reaction between oxygen and iron powder, thus melting oxides as fast as they form. Molten iron oxide from the reaction fluxes and dilutes the refractory oxides to form a fluid slag which is easily washed away by the torch flame.

Steel analysis may restrict use of flame washing because of cracking danger. Castings under 0.30% carbon, however, can be washed readily, and even those with up to 0.50% carbon may be processed if the work is performed while the castings are still hot.

Gates and risers must be removed first by oxy-acetylene cutting torch, leaving pads no higher than ½ in. for subsequent flame washing.

Manipulation of the torch is vitally important, either an oscillation with a forward motion or a counterclockwise elliptical motion combined with forward travel being recommended. Pads larger than 4 in. in diameter require more than one washing pass.

Stainless and other high-alloy steel castings cannot be flame washed except by use of the ferrous powder addition. The same applies to cast iron.

ARTHUR H. ALLEN

Stability
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New 64 cu. ft. production unit brings 350 lbs. of AM-350 stainless steel per hr. from ambient to minus 120° F.

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Member, Environmental Equipment Institute

Zone Refining of Copper

Digest of "The Zone Refining of Impure Copper", by E. D. Tolmie and D. A. Robins, *Journal*, Institute of Metals, Vol. 85, January 1957, p. 171-176.

TO THOSE acquainted with the zone refining of germanium, the reaction of copper to zone refining may seem disappointing. Only in the zone refining of germanium has the purification reached a parts per ten million figure, while chromium and manganese are the only other metals to have reached a parts per one million figure or better. In these microscopic quantities, difficulty is experienced in estimating impurity: For germanium, conductivity is used as a yardstick of purity, and in experiments with copper, results are based on spectrographic measurements obtained by the molten-globule technique.

Results indicate that the phase

These typical 19 together took 91

Here are 19 discriminating buyers whose 91 orders and repeaters prove complete satisfaction with these UNITRON instruments.

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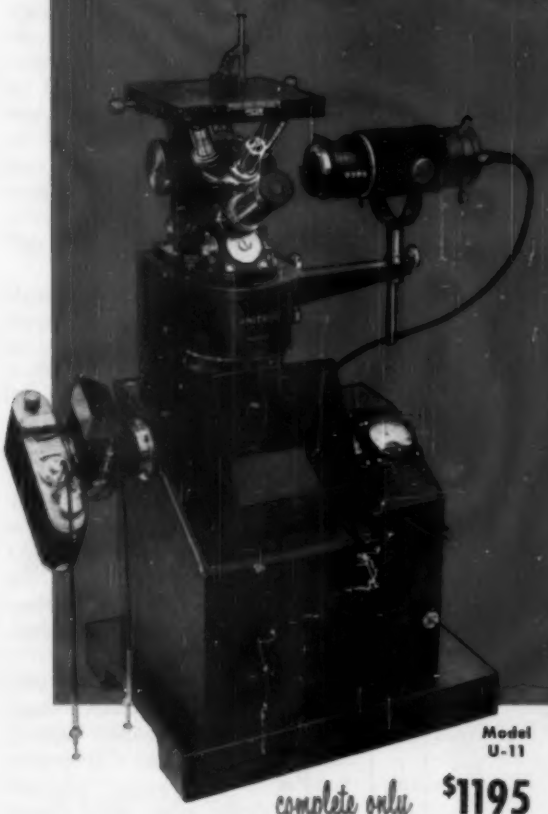

Model U-11

complete only $1195

BINOCULAR MODEL only $1379

UNITRON METALLOGRAPH and Universal Camera Microscope, Model U-11: A completely self-contained instrument of modern design for visual observation, photography, projection and measurement of both opaque and transparent specimens, using bright-field, dark-field or polarized illumination. While compact in size, it duplicates the performance of large, cumbersome instruments. Even laboratories on a limited budget can enjoy the accuracy, speed and efficiency possible only with a complete installation of this type.

- Standard optics include 5 parfocal objective lenses with revolving nosepiece, 4 photographic eyepieces on a revolving turret, 3 visual eyepieces, all coated. Magnification range: 25-2000X.
- High-intensity illuminator with variable transformer built into the microscope base.
- Built-in 3¼" x 4¼" camera. The image is automatically in focus in the camera and transition from observation to photography is instantaneous.
- Calibrated square mechanical stage with calibrated rotatable stage plate.
- Calibrated polarizing apparatus, transmitted-light accessories for transparent specimens, filters, micrometer eyepieces, film holders, cabinets, dustcovers, etc. all included.
- Additional accessories, available at extra cost include: Polaroid Land Camera attachment for "60-second" photography; 35mm camera attachment; low power (5-40X) objectives; vacuum heating stage for temperatures to 1100°C.

Model MEC

complete only $399

BINOCULAR MODEL only $599

UNITRON INVERTED Metallurgical Microscope, Model MEC: Many of the features of the UNITRON Metallograph U-11, which are connected with visual observation of opaque specimens, are included in this compact unit. Think of the time which can be saved in your laboratory by providing each metallurgist with one of these handy, inexpensive units for use at his desk. Model MEC is also ideal for use together with a polisher or microhardness tester.

- Standard optics include 4 parfocal objective lenses: 5X, 10X, 40X, 100X oil immersion on revolving nosepiece; 3 eyepieces: P5X, Micrometer 10X, Ke15X, all coated. Magnification range 25-1500X.
- Vertical illuminator with iris diaphragm. Transformer housed in microscope base. A microswitch on the base provides an extra high intensity for photography.
- Binocular model has provision for attaching 35mm camera to microscope base. A 35mm camera attachment is available to attach to the eyepiece tube of the monocular model.
- Calibrated square mechanical stage with calibrated rotatable stage plate.
- Calibrated polarizing apparatus, 5 filters, dustcover, cabinet, etc. all included.
- Additional accessories available at extra cost include: 35mm camera attachment; K20X eyepiece for 2000X; transmitted-light accessories for transparent specimens; vacuum heating stage.

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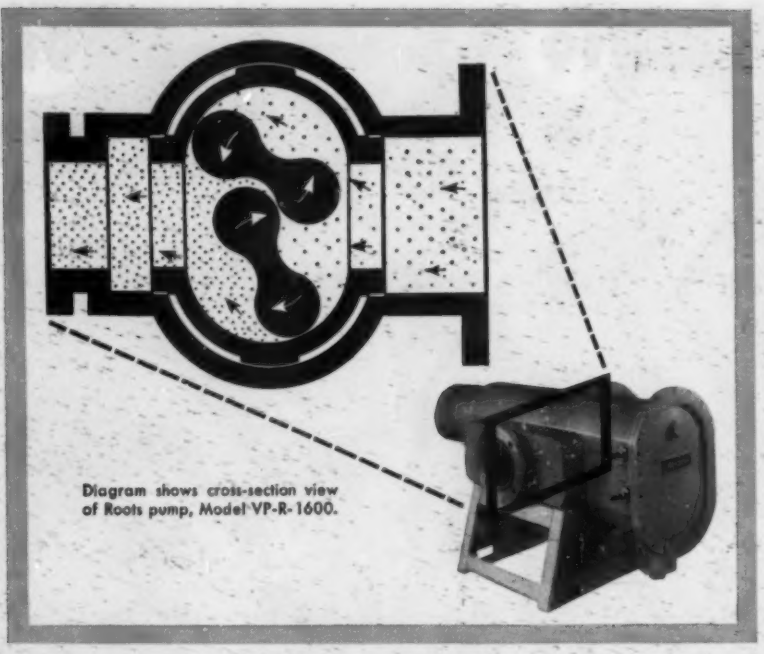


Diagram shows cross-section view of Roots pump, Model VP-R-1600.

How to get vapor-free high vacuum

fast . . . with the ROOTS pump

Now you can achieve completely dry pressure in the 10^{-1} to 10^{-5}mm Hg range using only a *mechanical* high-vacuum pump.

Probably the world's fastest pump in this range, the new Roots pump works without the aid of oil or steam vapors.

A pair of finely machined rotary pistons do the pumping. The pistons never touch one another or the pump casing, so the Roots pump needs no oil sealing. It cannot contaminate a system with backstreaming vapors.

Consider these other advantages:

1. Speed. The model shown above has a throughput of 10,400 micron cu. ft. per minute at 10 microns.

2. No shaft seals, no leaks. Motor operates within the vacuum.

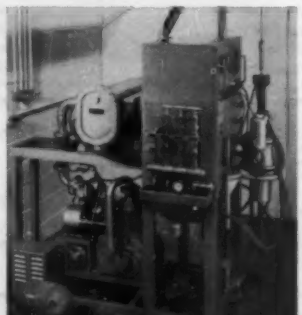
3. No by-pass or valving. Roughing is done directly *through* the pump.

4. Quiet. The Roots pump does not vibrate when in operation.

5. Low power consumption.

Under a license with the manufacturer, Heraeus (Hanau, Germany), CEC is exclusive agent for all seven models of the Roots pump in this country.

For data on performance and theory of operation, write for Bulletin P8-20.



Heraeus Vacuum Arc Melting Furnaces are also available from CEC. Note Roots pump used. Furnace melts "buttons" to ingots. Particularly useful for obtaining pure samples of metals with high melting points. Information in Bulletin P4-28.

Consolidated Electrodynamics

Rochester Division, Rochester 3, N. Y.

SALES AND SERVICE OFFICES IN PRINCIPAL CITIES

Zone Refining . . .

diagrams of copper binary systems may be used to estimate the segregation characteristics of alloying elements during zone refining of dilute copper alloys. Calculations of the partition coefficient of zone-refined copper compare reasonably with the partition coefficient obtained from the phase diagrams. One assumes that the differences that occur can be attributed to inherent control difficulties.

In the process, oxygen-free high-conductivity copper having a copper content of 99.99% was used. Major impurities remaining were 0.003% S, 0.003% Ag, and 0.0007% Ni. All the added alloying elements contained less than 0.5% of the total impurity.

Initial Refining – Concentrated alloys were made in a magnesia crucible under an atmosphere of pure hydrogen, using high-frequency heating. Alloy "A" contained chromium, cobalt, iron, nickel and silver, each at a concentration of 0.05%, balance copper. Alloy "B" contained antimony, chromium, cobalt, iron, manganese, nickel, silicon, silver and tin each at a concentration of 0.01%, balance copper. (These master alloys were diluted to the required composition by remelting with additional quantities of copper.)

The copper ingots were cold rolled to a bar 9 mm. (0.35 in.) square and cut into 20-cm. (7.87-in.) lengths. The surface of the bars was cleaned first mechanically and then chemically with 60% nitric acid. A portion was removed from each bar for spectrographic analysis.

Zone Refining – A high-purity graphite boat, degassed at about 2800° C. (5070° F.) in a graphite resistor furnace, carried the copper bar. The boat was then placed inside a transparent silica tube through which passed dried and purified hydrogen. The boat was conveyed mechanically at controlled speed along the silica tube. The sample was heated at the midway point by a 25-kw. induction coil which surrounded the silica tube. The added elements iron, cobalt, and nickel segregated to the starting end of the bar, and the others to the finishing end.

H. J. Roast

Metal Progress

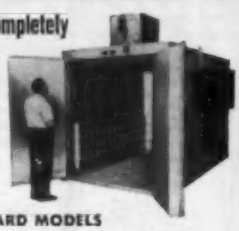
Bulletin Board...

The Buyers Guide For Metals Engineers

GRIEVE-HENDRY
WALK-IN OVENS

Shipped Completely "Set-Up"

Previously Tested and ready to operate.



6 STANDARD MODELS

No engineering charges

Latest convenience features and safety devices included. Design changes to suit requirements. Electric, gas or oil heated. Write for bulletin.

87 Standard Bench and Cabinet Models $110.50 and up

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CHICAGO 7, ILL.

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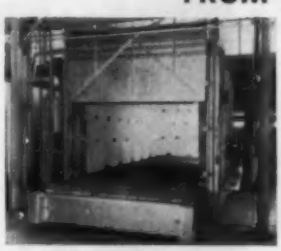
PACIFIC FURNACES ARE ENGINEERED
FROM THE INSIDE OUT



The special wall holding anchor tiles developed and patented by Pacific have solved the problems of furnace wall failures due to unequal expansion and contraction of inner and outer wall surfaces. These wall holding anchor tiles save rebuilding time, costs and are GUARANTEED FOR FIVE YEARS.

Pacific ENGINEERS. . . . BUILDS. . . . SERVICES all types of industrial heating equipment.

FOR COMPLETE INFORMATION ON OUR SERVICES —WRITE OR CALL

THE Pacific INDUSTRIAL FURNACE CO.
24680 Telegraph Road, Detroit 19, Michigan
Phone: Kenwood 3-6900

LIST NO. 173 ON INFO-COUPON PAGE 170

STANWOOD HEAT TREATING EQUIPMENT RETORTS and STACKING BASKETS

• REPRESENTATIVES IN PRINCIPAL CITIES

of new Cor-Wal construction give you:

- Lighter weight—yet stronger
- Longer service life
- Sides are heat resistant corrugated rolled metal
- Basket grid, grid supporting ring and top ring are of high temperature cast alloy
- Proved in exhaustive tests on the job

WRITE FOR DETAILS

STANWOOD CORPORATION
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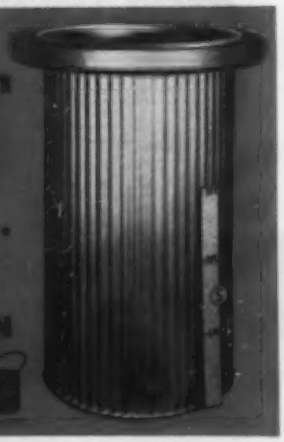

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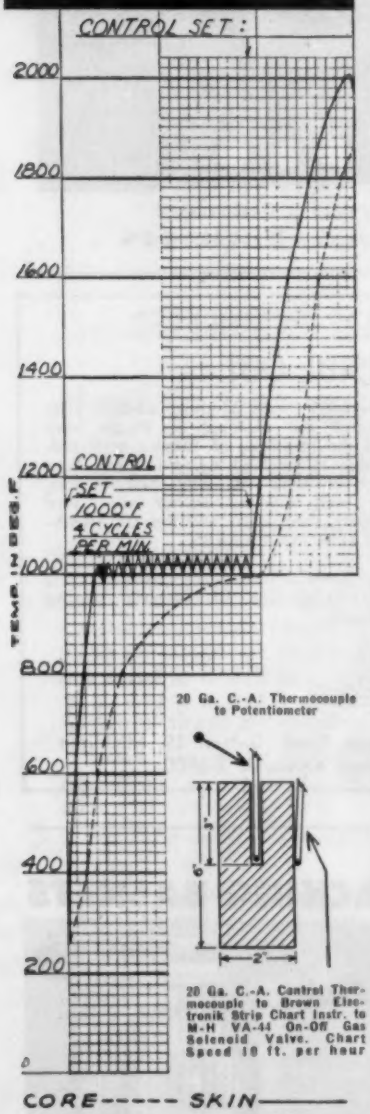
Instantaneous Heat!

Firing Rate: 50,000 B.T.U. Per Sq. Ft.
Blower Air — 117 C.F.M.



INSPECT THIS PROVEN COMBUSTION SYSTEM

THE A. F. HOLDEN COMPANY
14341 Schaefer Highway
DETROIT • MICHIGAN

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HIGH-DENSITY SINTERED METAL PARTS

carburized tensile strength to 200,000 psi.

Supermet combines the economy of powder metallurgy with the properties of controlled carburization to give you solid steel parts at low cost. Seven ranges of properties available in electrolytic iron; we also invite stainless steel parts. As an indication of accuracy, we are currently pressing AGMA commercial class 4 spur gears. Send a part print for evaluation.

Supermet Division
GLOBE INDUSTRIES, INC.
1465 Cincinnati St. Dayton 8, Ohio
free technical literature

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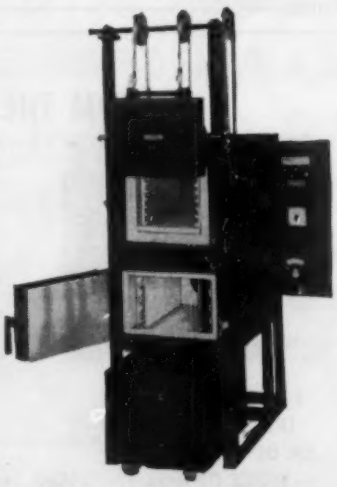

SAVE SPACE WITH A
SERIES 8055
COMBINATION MODEL

Two independent furnaces (hardening and drawing) in the same floor space one requires. Complete with independent controls. Hardening furnace available in both a 2000° and a 2300° F. range.

Drawing furnace has a maximum of 800° F.* Quench tank included with the exception of the largest standard model.

	Chamber Size			Prices	
Model	H.	W.	L.	2000° F.	2300° F.
8055 A	6"	x 6"	x 12"	$ 865.00	$ 975.00
8055 B	9"	x 9"	x 18"	1325.00	1450.00
8055 C	12"	x 12"	x 24"	1850.00	1950.00
8055 D	18"	x 18"	x 36"	2750.00	2875.00

*Also available up to 1250° F.

WRITE FOR FREE LITERATURE, SPECIFICATIONS and price list of Lucifer Furnaces in wide range of sizes—top loading and side loading types. Engineering advice without obligation. Write, wire or phone today.

LUCIFER FURNACES, INC.
NESHAMINY 7, PA.
Phone: Diamond 3-0411

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FREE
the QUENZINE STORY

Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .

KELCO

ALDRIDGE INDUSTRIAL OILS, Inc.
3401 W. 140th St., Cleveland 11, Ohio

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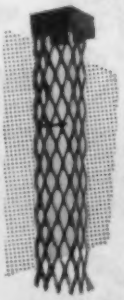
there's a
Glo-QUARTZ*
IMMERSION HEATER
for
Your Every Heating Requirement



- INSTANT HEATING
- SHOCK-PROOF
- AVAILABLE IN ALL VOLTAGES —WATTAGES, ONE AND THREE PHASE

Available from your Electroplating Distributor

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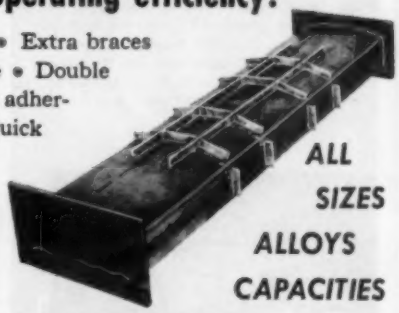
ELECTRIC HEATER CO., INC., Willoughby, Ohio
*Reg. U. S. Pat. Off. Phone: Willoughby 2-5521

LIST NO. 145 ON INFO-COUPON PAGE 170

WIRETEX custom built MUFFLES
assure labor saving operating efficiency!

Features: • High crown • Extra braces • Capacity for holding shape • Double secured weldments • Strict adherence to specifications • Quick delivery • Low cost



ALL SIZES ALLOYS CAPACITIES

WIRETEX designed MUFFLES offer exceptional opportunities to lower costs. Built to take extremely high temperatures and strong atmospheric conditions. If you have a sintering furnace problem or are dissatisfied with the results you are now getting, let us help you.

Before You Buy Muffles . . . See WIRETEX

Wiretex mfg. co.

Specialists in Processing Carriers Since 1932. 5 Mason St., Bridgeport 5, Conn.

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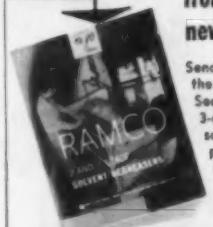
Q A METAL PARTS CLEANING PROBLEMS?

Get the answers RIGHT from RAMCO'S new BULLETIN!



Send for your copy of the Ramco Bulletin. See how Ramco 2- and 3-dip degreasers can solve your metal parts cleaning problems, economically, efficiently, safely! Write today!

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DIV. OF RANDALL MFG. CO., INC.
809 Edgewater Rd., New York 59, N.Y.

LIST NO. 128 ON INFO-COUPON PAGE 170

RUST-LICK
IN AQUEOUS SYSTEMS

Eliminates RUST & Fire Hazards Non-Flammable Non-Toxic

Send for Brochure:
The ABC of Rust-Lick for Rust Prevention

PRODUCTION SPECIALTIES, INC.
755 BOYLSTON STREET
BOSTON 16 MASS

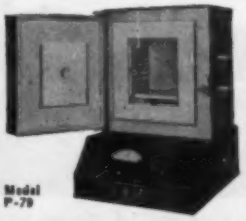
LIST NO. 105 ON INFO-COUPON PAGE 170

PRODUCED AND PRICED RIGHT FOR YOUR ELECTRIC FURNACE NEEDS

DYNA-TROL

MODEL NO.	FIRING CHAMBER (H.W.D.)	PRICE (300° to 2000°)	PRICE (400° to 2300°)
P48	4½"x4½"x9"	$90.00	$110.00
P78	6"x6"x9"	$205.00	$225.00
P918	9"x9"x18"	$480.00	$528.00
P314	14"x14"x14"	$525.00	$603.25
P124	12"x12"x24"	$715.00	$822.25
P818	18"x18"x18"	$775.00	$887.50
P136	18"x18"x36"	$1125.00	$1312.50

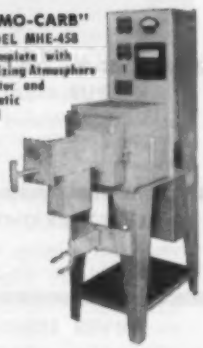
Automatic Controls Available on all Models



Model P-79

- Infinite zone temperature control
- Zone temperature indication by Pyrometer Selector Switch
- Automatic hold and cut-off instrument available
- Patented element holders
- Infinite variety of time-temperature curves obtainable
- Rugged construction

"ATMO-CARB" MODEL MHE-458
Complete with Carburizing Atmosphere Generator and Automatic Control



$1325.00
Other Sizes and Arrangements Available

L&L MANUFACTURING CO.
Chester 77, Pa.

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WANTED

SIR PLUS FURNACES

REWARD

WE PAY CASH FOR SURPLUS INDUSTRIAL FURNACES AND RELATED APPARATUS

SURPLUS FURNACES FOR SALE

BOX TYPE

24x36x18	Lindberg	50KW	2000°F
36x72x23	G.E.	72KW	2000°F
48x84x24	American	100KW	1850°F
24x36x14	Surface	Gas	1850°F
54x96x24	Surface	Gas	1850°F

PIT TYPE

20x22	G.E.	48KW	1200°F
28x28	Lindberg	52KW	1250°F
48x72	Lindberg	Gas	1250°F
48x96	Surface	Gas	1250°F
48x96	Lee Wilson	Rad. Tube	1850°F

CONVEYOR TYPE RECIRCULATING

72x40'x30	Surface	RlrHrth	Gas	1250°F
27x15'x12	R&S	MshBlt	Gas	1250°F
36x33'x12	Despatch	MshBlt	Gas	875°F

BOX TYPE RECIRCULATING

7'x7'x5'	Richards	84KW	450°F
6'x12'x42"	Lindberg	Gas	1250°F
4'x15'x6'	Despatch	Gas	850°F
24"x36"x24"	Lindberg	45KW	1400°F
66"x16'x76"	Lindberg	180KW	1250°F

PIT TYPE CARBURIZERS

14x18	L&N Vapo	11KW	1850°F
14x18	L&N Homo	30KW	1850°F
20x36	L&N Homo	72KW	1850°F
10x20	HeviDuty	14KW	1500°F
25x48 (New)	L&N Micro	100KW	1850°F

BRAZING TYPE

18x42x12	Lindberg Pshr	60KW	2500°F
28x17'x12	G.E. RlrHrth	320KW	2050°F
62x18'x24	G.E. RlrHrth	655KW	1650°F

SEND FOR COMPLETE LIST

THE JOE MARTIN CO., INC.

19256 John R. St. TWinbrook 2-5500 Detroit 3, Mich.

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Sel-Rex®

PRECIOUS METALS FOR INDUSTRIAL PLATING

BRIGHT GOLD

Mirror-bright finish in any thickness directly from the bath. Patented

PUR-A-SALTS

Restores contaminated cyanide plating baths to full, trouble-free operation. Patented

SILVREX BRIGHT SILVER

Crystal-clear solution that produces mirror-bright deposits. Patented

SILVER SOL-U-SALT

Non-dusting—safest and easiest to use.

BRIGHT RHODIUM

Brilliant, fine-grained non-tarnishing deposits.

RHODEX

Only rhodium electroplating process that yields extra heavy compressively stressed deposits. Patent Pending

ACID GOLD PLATING PROCESS

Developed specifically for plating printed circuits. Mildly acid so that neither the laminate nor the adhesive at the inter-face of printed circuit boards are affected during the plating process.

Complete installation and servicing on all precious metals processes.

SEL-REX CORPORATION

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Offices: Detroit, Chicago, Los Angeles

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GOOD USED EQUIPMENT AT REAL SAVINGS TO YOU!

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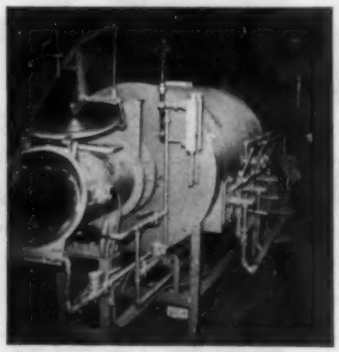

Lindberg "Iron Lung" Pusher

Our stock is constantly changing! Before you buy any furnace or accessory, call us collect and let us show you how to save money! (Money-Back Guarantee). We pledge that any unit we advertise is in stock at one of our warehouses at the original time of publication. However, they are subject to prior sale, so act now!

METAL TREATING EQUIPMENT EXCHANGE, INC.
9825 GREELEY ROAD
DETROIT 11, MICHIGAN

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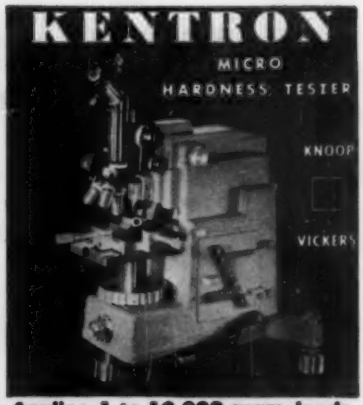
KENTRON

MICRO HARDNESS TESTER



Applies 1 to 10,000 gram loads

Write for Bulletin

Kent Cliff Laboratories Div.

The Torsion Balance Company

CLIFTON NEW JERSEY

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Controlled Atmospheres

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HEAT-TREATING BASKETS

All shapes, sizes, alloys.
Estimates without obligation.

THE C. O.
JELLIFF
MANUFACTURING CORP.
SOUTHPORT, CONNECTICUT

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make hardness tests
ANYWHERE
WITH THE
NEWAGE TESTER

- CLAMPS, JAWS & BASE PLATE ARE ELIMINATED
- NO CONVERSIONS OR CALCULATIONS
- TEST ANY SIZE, SHAPE OR TYPE METAL
- NO SKILL REQUIRED
- SCALE READINGS IN ROCKWELL & BRINELL
- ACCURACY GUARANTEED

Many thousands used by industry and government. Write, wire or call for additional details and prices.

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222 York Road, Jenkintown, Pennsylvania
TUrner 4-8696 Dept. MP

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STEEL FABRICATED and RUBBER-LINED TANKS for the Plating Industry

ARco

- Plating tanks any size or shape fabricated and rubber-lined to your specifications. A complete service from basic design to installation, also fabricated and rubber-lined pipe and fittings. Write Dept. "MP" for complete details.

Subsid. of Automotive Rubber Co., Inc.
ARco STEEL FABRICATORS • INC.
12542 BEECH ROAD • DETROIT 39, MICH.

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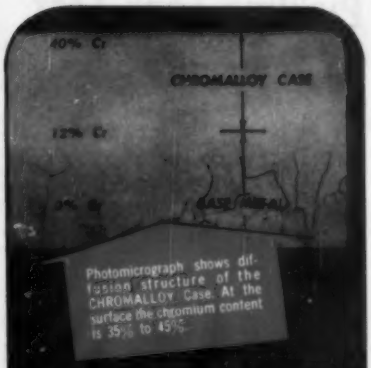


Photomicrograph shows diffusion structure of the CHROMALLOY Case. At the surface the chromium content is 35% to 45%

CHROMIZING PROCESS COMBATS...
HEAT
WEAR
CORROSION

CHROMALLIZING diffuses chromium into the surface of iron and steel parts, providing the corrosion resistance of stainless steel and the wear resistance of chromium carbides. CHROMALLOY Case cannot chip, peel or flake.

Chromalloy Corporation is fully equipped for processing large or small quantities of parts. Engineering advisory service available.

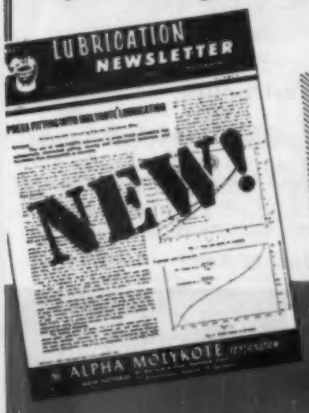
FREE! TECHNICAL BULLETINS

Chromalloy CORPORATION

451 Tarrytown Road, White Plains, N.Y.
Telephone White Plains 6-0020

LIST NO. 146 ON INFO-COUPON PAGE 170

Engineering Data on MOLYKOTE® lubricants



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- Every issue features a full-length technical article on the use of MOLYKOTE Lubricants in industry.
- "How-to" stories on tough lubrication applications
- Get on our mailing list TODAY. Write to

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Main Factories:
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71 Arnulfstrasse, Munich 19, Germany

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Technic Gold is in orbit with "Explorer"

Certain component parts of "Explorer", the first American satellite, required gold plating. Logical choice was Technic 24 karat INDUSTRIAL GOLD — the first and purest soluble 24 karat gold in the world. Or out of it!

UNIQUE PROPERTIES SOLVE UNIQUE PROBLEMS

Precious metals are finding extraordinary applications in industry and the laboratory. Electroplating offers an efficient method of exploring and exploiting such characteristics as the unique and diverse properties of gold — not found in combination in any other form.

TECHNIC SERVICE

If you have requirements for electroplated gold, other precious metals, or alloys — consult Technic. We equip you with controlled electroplating apparatus and/or solutions that eliminate variables, assure precise performance reproducible as often as required. Find out how Technic Service assures quality with economy.

Phone, wire, TWX or write . . .

160-B

TECHNIC, INC.

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Providence, R. I.
JAckson 1-4200
Chicago Office—7001
North Clark Street

THE LARGEST ENTERPRISE OF ITS KIND IN THE WORLD

LIST NO. 124 ON INFO-COUPON PAGE 170

Solve
Inspection
Sorting
Demagnetizing
Problems

with
MAGNETIC ANALYSIS...

MULTI-METHOD EQUIPMENT

Electronic equipment for non-destructive production inspection of steel bars, wire rod, and tubing. Detects mechanical faults and variations in composition and physical properties. Average inspection speed – 120 ft. per minute.

SPECIAL EQUIPMENT

Electronic equipment for non-destructive production inspection of non-ferrous bars and tubing . . . as well as both non-magnetic stainless and high temperature steel bars and tubing – seamless or welded. Mechanical faults, variations in composition and physical properties are detected simultaneously. Average inspection speed – 200 ft. per minute.

WIRE ROPE EQUIPMENT

Electronic equipment for inspecting ferromagnetic wire ropes from 1/32" to 3" diameter. Detects broken, cross-over or missing wires, plus defective welds and deformations at production speeds up to several hundred feet per minute.

COMPARATORS AND METAL TESTERS

Electronic instruments for production sorting of both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

DEMAGNETIZERS

Electrical equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

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Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

"THE TEST TELLS"
For Details Write:
MAGNETIC ANALYSIS CORP.
42-44 Twelfth St., Long Island City 1, N. Y.

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Pickling Tank Test in 3 minutes . . .

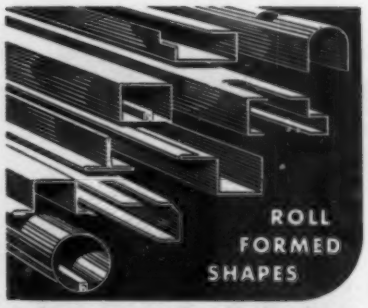
WITH FERRO PICKLE PILLS!

Any workman who can tell red from green and count to ten can test the exact strength of pickling solutions . . . *the exact percentage of iron content*, and the solution percentage of sulphuric acid, muriatic acid, alkali etc. in metal cleaning tanks.

Ferro Pickle Pills provide a quick, accurate test to augment periodic titration testing, or as a "test within a test". They can assure full-capacity cleaning with fewer rejects, save money by eliminating premature dumping of tanks. That's why more and more companies are using them. Why don't *you* try them? Write today for literature and prices.

FERRO
FERRO CORPORATION
4133 East 56th Street
Cleveland 5, Ohio

LIST NO. 175 ON INFO-COUPON PAGE 170



Reduce your assembly problems and costs. Our shapes continuously formed, with high degree of accuracy, from ferrous or non-ferrous metals. Write for Catalog No. 1053.

ROLL FORMED PRODUCTS CO.

MAIN OFFICE AND PLANT
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LIST NO. 101 ON INFO-COUPON PAGE 170

Need Help Designing That Aluminum Extrusion?

TEAM UP with JARL

THERE'S A WORLD OF DIFFERENCE

The *difference* starts the moment you meet the Jarl salesman. He's an engineer . . . well qualified to make on-the-spot recommendations in designs. Team up with Jarl and you'll get the right shapes made to most exacting design specifications. You'll be sure of close die control . . . quality safeguards every step . . . on-time deliveries. Send for our stock die catalog or send rough sketches for assistance with your design.

ANODIZING
JARL EXTRUSIONS, INC.
Dept. MP, Linden Ave. • East Rochester, N. Y.

LIST NO. 165 ON INFO-COUPON PAGE 170

ULTRASONIC
Thickness Testing from One Side

Rapid, Accurate, Non-Destructive

VIDIGAGE®

14" or 21" Cathode-Ray Screen with direct-reading scales between 0.005" and 2.5"; accuracy 0.1% to 1.0%.

AUDIGAGE®

Portable Thickness Testers for ranges from 0.020" to 4" or 0.060" to 12" of steel; accuracy up to 1.0%.

Detect Laminar Flaws and Lack of Bond

BRANSON INSTRUMENTS, INC.
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Specializing in Ultrasonics Since 1946

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HOOVER

SPECIALISTS IN THE FIELD OF

Die Castings

SINCE 1922

Aluminum and Zinc

THE HOOVER COMPANY
Die Castings Division
North Canton, Ohio
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END POT FAILURE

Switch to *scheduled* pot maintenance with low-cost pressed-steel pots for lead, salt, cyanide, oil-tempering, metal-melting. Can't turn suddenly defective, because no faulty steel survives drawing. Request catalog from Eclipse Fuel Engineering Co., 1127 Buchanan St., Rockford, Ill.

Eclipse INDUSTRIAL COMBUSTION DIVISION

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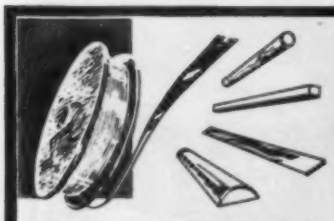

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Beryllium Copper • Bronzes
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Available with hot-tinned finish for solderability.
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INCORPORATED
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Whitelight MAGNESIUM

your comprehensive independent mill source of magnesium alloy . . .

ALLOYS
AZ10
AZ31
AZ51
AZ61
AZ81
ZK60
ZK30
M-1
HK31
HM21

RODS ⅛" dia. to 6½" dia.
BARS, STRIPS .022" min. to 7¾" max.
SOLID SHAPES .022" min. to 6½" circle
TUBING ⅛" O.D. to 6" O.D.
HOLLOW SHAPES ½" to 6½" circle
PLATE & SHEET .032" to 3" thick

WHITELIGHT MAGNESIUM

WHITE METAL ROLLING & STAMPING CORP.
82 Moultrie Street Brooklyn 22, N.Y.
Factories: Brooklyn, N.Y. • Warsaw, Ind.

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How Roll Coater

Pre-Painted

METAL SAVED MONEY AND IMPROVED QUALITY ON

R-C-000 LICENSE PLATES

PROBLEM:

Stello Products Company, Logansport, Indiana, manufacturer of tags, license and "booster" plates, had the problem of excessive direct labor charges. In the previous expensive method of making these items, plates had to be stamped from bare metal —and then cleaned individually—and spray painted on both sides. This method did not give the uniform quality demanded—and Stello turned to Roll Coater for a solution.

SOLUTION:

Roll-coated metal was tested by Stello Products Company. *Pre-painted* and *baked* on both sides, this metal eliminated *entirely* the cleaning and spray painting operations—withstood rigorous stamping tests—and relieved painting facilities for other jobs. Says J. C. Cotner, president of Stello Products Company, "Roll Coater metal is now saving us approximately 50% in direct labor costs—and is giving us the desired uniform quality in our plate production. It really solves our problem."

SEND FOR FREE BROCHURE and SAMPLE TODAY!

Roll Coater
INCORPORATED
PENDLETON • INDIANA

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THE NEW
DERMITRON

NON-DESTRUCTIVE COATING THICKNESS TESTER

FAST... ACCURATE NON-DESTRUCTIVE DIRECT-READING

- Instantly measures the thickness of metallic and non-metallic coatings and films
- Based on eddy-current principles
- Enables measurements on small or otherwise inaccessible areas

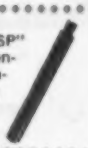
This portable instrument for both laboratory and production use, gives fast, accurate and direct readings of virtually any coating on any base, including:

- Metal coatings (such as plating) on metal base (magnetic and non-magnetic)
- Non-metallic coatings (such as paint, anodizing, hard-coat, ceramic) on metal base
- Metal films (such as vacuum metallizing) on non-metallic base (plastics, ceramics)

MEASURING PROBES ARE AVAILABLE IN THE THREE TYPES SHOWN BELOW

NEW RIGHT-ANGLE PROBE model "RP" enables measurements in holes down to ½" I.D.

STANDARD PROBE model "SP" enables measurements on convex surfaces down to ⅛" radius of curvature and on concave surfaces down to 2" radius of curvature



MODIFIED STANDARD PROBE model "MP" enables measurements on concave surfaces down to ¼" radius of curvature

Each of the above probe types is available in 4 different thickness ranges—A, B, C and D, from thick to thin deposits.

Write for latest bulletins and questionnaire to help solve your thickness testing problems

UNIT PROCESS ASSEMBLIES, INC. UPA

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the GENUINE BRINELL

HARDNESS TESTING MACHINES made by the Alpha Co. of Sweden and available from our stock at New Rochelle

Never approached in ACCURACY AND CONSTANCY of calibration . . . at the standard 3000kg test load . . . maximum error plus or minus 2½ kg

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GRIES INDUSTRIES, INC.
Testing Machines Division
NEW ROCHELLE 3 N Y

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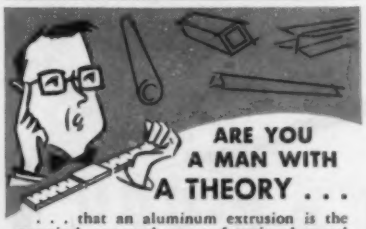

ARE YOU A MAN WITH A THEORY . . .

. . . that an aluminum extrusion is the practical approach to a functional metal parts application . . . at a savings in time and money, and without loss in quality? In fact, the properties — you theorized — of extruded aluminum would even be better? If so, G.E.I.'s engineers are ready to consult with you — without obligation, on one part or a million — to determine how practical your idea is. G.E.I. engineers specialize in adapting extruded aluminum to *new* functional roles.

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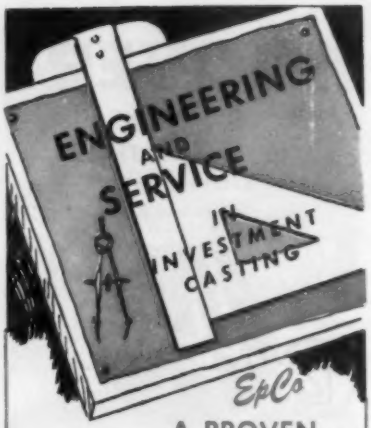

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ENGINEERED PRECISION CASTING CO.
MORGANVILLE, N. J.

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Integrate your marking operations by utilizing present equipment and incorporating a Matthews' Marking Device! **Matthews will machine and engrave a die or type to suit your product. Our complete line of Type and Die Holders, too, are easily designed to fit existing press equipment. Write or call today for additional information.**

JAS. H. MATTHEWS & CO.
Over 100 Years of Service to Industry
3968 Forbes St. • Pittsburgh 13, Pa.

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HAWKRIDGE METALS CORPORATION

Producers and Sellers of

TITANIUM POWDER

−40 to +300 mesh

High Purity	99.2% Pi
Commercial	98.6% Pi

North Hampton
New Hampshire

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HARDNESS TESTING SHORE SCLEROSCOPE

Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

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90-35M Van Wyck Exp., Jamaica 35, N.Y.

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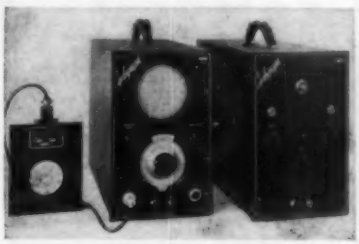

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. . . for unscrambling metal mixups

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Complete Arc Welding Accessories
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Write for Caddy Catalog

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Frank UNIVERSAL HARDNESS TESTER

It combines tests for Rockwell B and C, Brinell and Vickers in one low-priced machine with NEW push-button load-selector and automatic zeroing for dial gage.

Request Catalog 505

OPTO-METRIC TOOLS, INC.

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TensilkuT machines a wide range of metals including steel, aluminium, stainless steel, copper, titanium, uranium, lead, the super alloys and all plastic materials.

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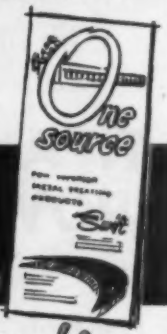

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CORPORATION

Plants: Bridgeville and Titusville, Pa., and soon in Coshocton, Ohio

Subsidiary plants: Mansfield and Dover, Ohio

Effect of Phosphorus and Manganese on Temper Brittleness

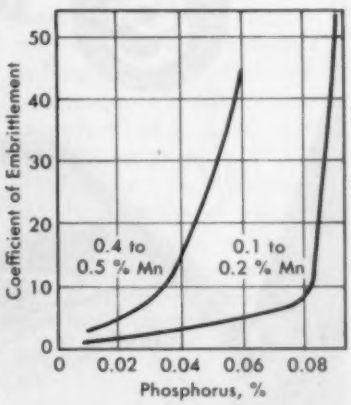
Digest of "Effect of Phosphorus and Manganese on Temper Brittleness in Chromium-Nickel Steel", by N. V. Tolstoguzov and A. D. Kramarov, *Metallovedenie i Obrabotka Metallov* (Russia), No. 2, 1957, p. 30-39.

AN IMPRESSIVE SERIES of articles on temper brittleness has been appearing in this Russian journal. The present article establishes some important relations between the occurrence of temper brittleness and the amounts of phosphorus, manganese and molybdenum in the steel.

To avoid effects due to steelmaking practice, the 20 steels studied were made as special melts in a 220-lb. electric arc furnace. Also, many of the steels were made in pairs from the same melt; powdered ferrophosphorus was added to one of the steels, while the other was left with a lower phosphorus content. Such pairs of steels were especially comparable and their manganese contents were identical. The phosphorus contents of the 20 steels ranged from 0.005 to 0.09% and the manganese from 0.07 to 0.75%. The other elements were relatively constant and averaged 0.4 C, 0.3 Si, 1.4 Cr and 3.0 Ni. Molybdenum up to 0.15% was present in a few steels.

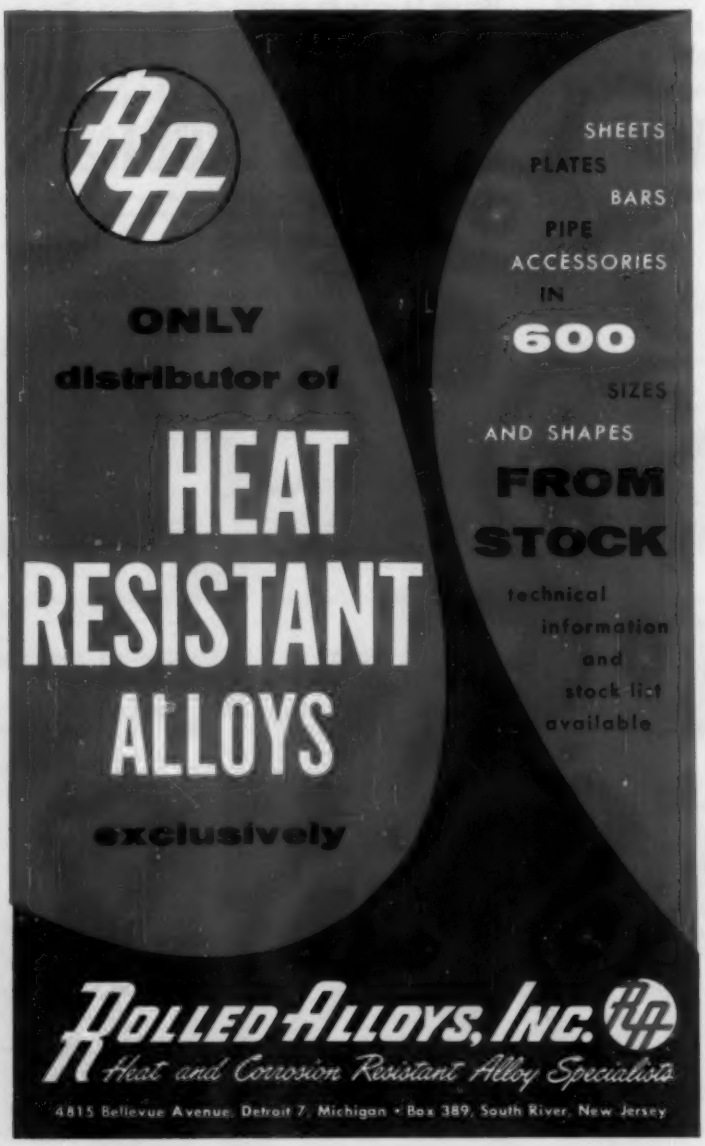
The 40-lb. ingots, given the usual soaking, forging and cropping, were cut into 0.8 × 0.8-in. bars, and after heat treatment were machined into notched-impact specimens. Testing, mostly at room temperature, was done on a 110 ft-lb. machine, and a few tests were made at temperatures down to —76° F. A coefficient of embrittlement was calculated as the ratio of the impact strength of the unembrittled steel (for example, steel that was water quenched from the tempering temperature) to the impact strength of embrittled steel (for example, steel that was furnace cooled from the tempering temperature).

One series of specimens was hardened by oil quenching from 1550° F., tempered for two hours at 1110° F., and then half of the specimens were water quenched from the tempering temperature and the other half were given an opportunity to develop temper brittleness by being cooled in the furnace from this temperature. Results of the room-temperature impact tests on these specimens are shown in the figure. At low manganese contents (0.1 to 0.2%), normal amounts of phosphorus cause only a slight tendency towards temper brittleness. At higher manganese contents, on the other hand, even small amounts of phosphorus cause a rapid increase in embrittlement, and at 0.04% P the coefficient is 15.



Room-Temperature Impact Tests Show Effect of Manganese and Phosphorus on Embrittlement

Further tests showed that the amount of molybdenum needed to



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1

2

3

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3 *Large capacity vertical furnace for heat treating large parts.*

The three furnaces shown on this page are units of the facilities of commercial heat treating plants in three different sections of the country.

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Temper Brittleness . . .

prevent temper brittleness depended on the amount of phosphorus in the steel when the manganese was kept constant at the low value of 0.13%. In steels containing 0.01% P, 0.05% Mo was sufficient to prevent temper brittleness, both at room temperature and for tests at —76° F. When 0.03% P was present, 0.15% Mo prevented temper brittleness at room temperature, but in tests at —76° F. the coefficient of embrittlement was found to be 1.85. It was concluded that a reduction could be made in the amount of molybdenum added to prevent temper brittleness if the phosphorus and manganese contents of the steel were held at low values. In fact, if the phosphorus and manganese contents are held down low enough (for example, 0.07% Mn and 0.007% P, even without any addition of molybdenum, steels show no temper brittleness at room temperature and only slight embrittlement at —76° F.

A. G. Guy

Metallurgy in Industry...

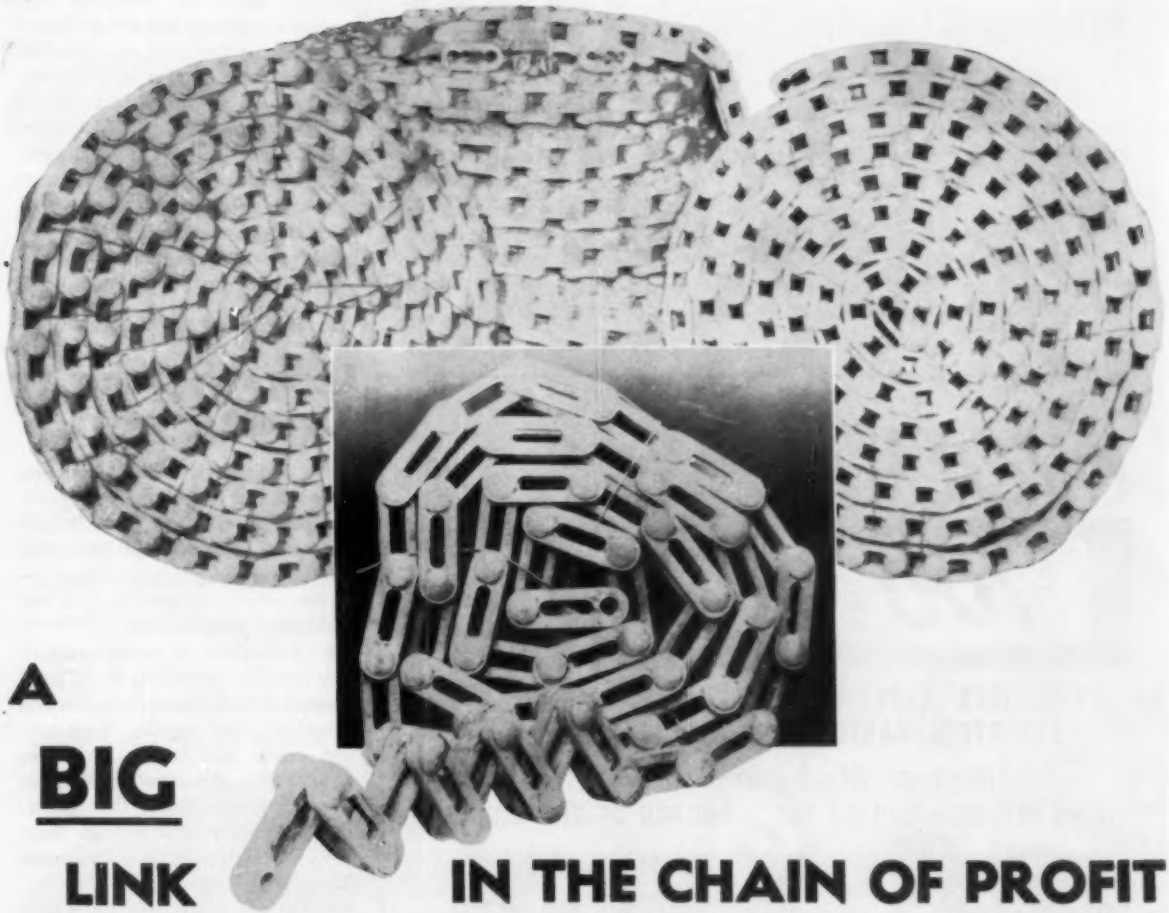
(Starts on p. 109)

Consequently when a new furnace is built, there is little quantitative basis for making significant design changes to meet the needs of our modernized burdens.

It must be perfectly clear that this problem will not be adequately solved by construction of a miniature blast furnace – whatever that may be. We need many different model devices to study the blast furnace process, and very likely none of them would bear a physical resemblance to the full-scale unit. One can visualize a long-range program using such devices that would lead to the answers desired, at considerably less cost and with far more useful results than are gained in the typical trial in an existing furnace.

A successful team in this field calls for skills that range from those of the mathematician to the aerodynamicist, supported by the experts in thermodynamics and kinetics.

University and Industry – This look ahead at metallurgy in industry has turned up areas in which both industry and the university researcher have a major role to play –



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ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

Metallurgy in Industry...

the expansion of our reservoir of kinetic data and the development of those basic concepts leading to reliable process studies on a manageable scale. For these and other basic metallurgical facts, we look forward to the continuing productivity of Carnegie Tech's Metals Research Laboratory.

There have been times in the past 25 years, I feel sure, when the laboratory has felt that the basic data derived from its efforts went crying in the wilderness for a receptive and dynamic understanding by industry. We all know of the many changes that have occurred during these same 25 years. Not the least is that metallurgists as a class have entered practically all functional areas of industry organization with favorable effect on the atmosphere and climate for utilizing basic scientific data.

Thus, while we recognize that process metallurgy has not advanced as rapidly as the need, the penalties of this deficit are now more widely recognized. As a result, I believe this clearer view of our requirements will lead to a much closer professional relationship between research men in university and in industrial laboratories, whereby the necessary basic scientific information can be derived and put to good use.

Atomized Aluminum . . .

(Starts on p. 70)

tively insoluble in solid aluminum, the small and well-dispersed constituent particles can be carried through subsequent stages of fabrication and into the finished product without going into solution or increasing in size at elevated temperatures.

2. Extrusions of some atomized alloy powders containing fairly large amounts of such elements as iron and chromium, had tensile, stress-rupture, creep, and fatigue properties (along with structural stability at elevated temperatures) that generally compared favorably with those of other high-temperature aluminum alloys recently developed. A complex alloy of 7.8% Fe and 0.2% each of Cr, Ti, V, and Zr (named M 486) had outstanding properties in the range from about 400 to 800° F.

3. Results, including some not published in this paper, indicate that for a given tensile strength level at 600° F. the atomized powder alloys tend to have better fatigue properties but slightly poorer creep characteristics than the aluminum-aluminum oxide type of powder alloy, M 276. (*Continued on p.* 178)

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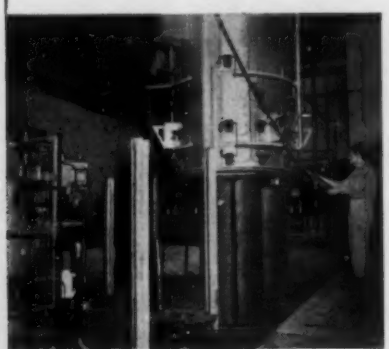

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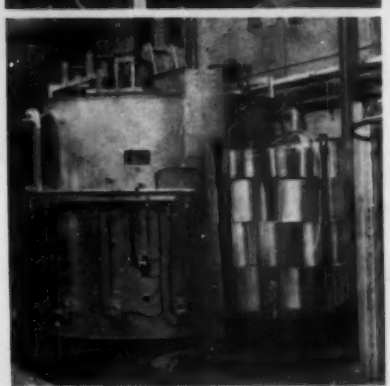

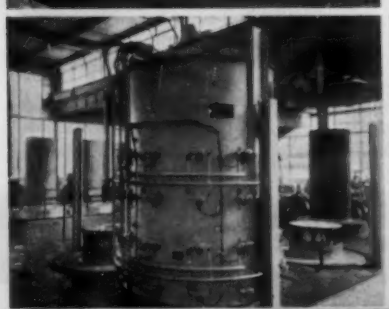

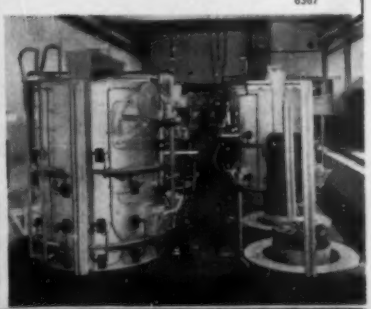

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Atomized Aluminum . . .

4. Ductility of atomized powder alloys increases with temperature—thus being similar to conventional alloys—in contrast to that of the SAP and APM products made from unalloyed flake powders of high oxide content, which decrease in ductility at high temperatures. This gives the atomized powder alloys an advantage in meeting service specifications and in hot working operations.

5. The relatively large amounts of iron, chromium, and other added alloying elements produce a high modulus of elasticity without prohibitive increase in density.

6. Increased strength may be obtained in extrusions of atomized alloy powders through decreasing the dendrite size (starting with a finer powder), as well as by increasing the amount of alloy.

7. The fabrication of products from atomized alloy powders could probably be extended to other systems besides aluminum alloys with beneficial results.

Nitrogen and Vacuum Degassing of Al-Si-Mg

Digest of "Effect of Nitrogen and Vacuum Degassing on Properties of a Cast Aluminum-Silicon-Magnesium Alloy (Type 356)", by R. K. Owens, H. W. Antes, and R. E. Edelman, American Foundrymen's Society Preprint No. 57-30, 1957, 7 p.

POROSITY IN aluminum castings can cause pressure unsoundness and structural weakness; shrinkage and dissolved hydrogen are the principal contributing factors. Shrinkage porosity is minimized by proper directional solidification and feeding. Once excessive hydrogen has been absorbed it must be removed before pouring to prevent unsoundness. This is accomplished by degassing, using vibration, bubbling or fluxing with a gas or vapor formed from a solid or a liquid, evacuation of the melt, holding under a dry atmosphere, and stirring to accelerate the degassing process.

All methods use one or both of the two basic mechanisms: precipitation of a bubble of molecular

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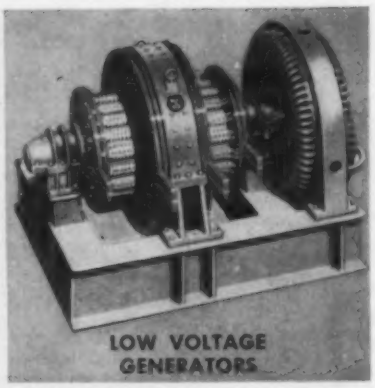

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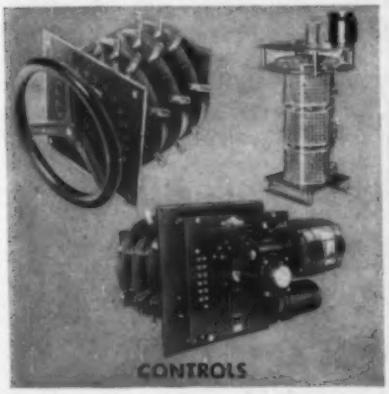

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Degassing . . .

hydrogen which rises to the surface, and a diffusion-desorption process, as in purging a melt with nitrogen. When vacuum degassing molten aluminum, both mechanisms of gas escape occur. Because of high initial cost and long holding times, these techniques have largely been confined to the laboratory. However, recently developed apparatus of the Naval Research Laboratory, using simple mechanical vacuum pumping equipment, will degas aluminum or other nonferrous alloys in 10 to 15 min.

Gassy melts of aluminum alloy 356 were degassed in a vacuum by the authors for times varying between 2 and 10 min., using dry nitrogen. With increasing degassing time the reduced pressure density was improved. Specimens were sectioned and polished. Macrographs showed that metal degassed for 10 min. by both the nitrogen and vacuum treatments produced sound metal.

The general effect of porosity in any casting is a decrease in mechanical properties; in aluminum alloys the greatest decrease is caused by the first 1% voids. Tensile and yield strength values increase uniformly as a function of decreasing gas content. A degassing time of 10 to 15 min. is necessary to provide gas-free metal when either vacuum or nitrogen degassing is used. For equal degrees of soundness no differences in tensile properties were noticed as a result of substituting vacuum degassing for nitrogen degassing. Differences noted in the mechanical properties of virgin and remelted heats could possibly be due to the loss of the grain-refining characteristics imparted by titanium.

The only advantage of vacuum over nitrogen degassing appears to be a smaller number of inclusions in vacuum heats. Vacuum degassing equipment is expensive, and heat losses during degassing are disadvantageous.

The authors conclude, therefore, that vacuum degassing should not take precedence over other good degassing techniques now commercially employed. They recognize that hydrogen has an extremely detrimental effect on the tensile properties of cast 356 remelt alloy.

HANS HEINE

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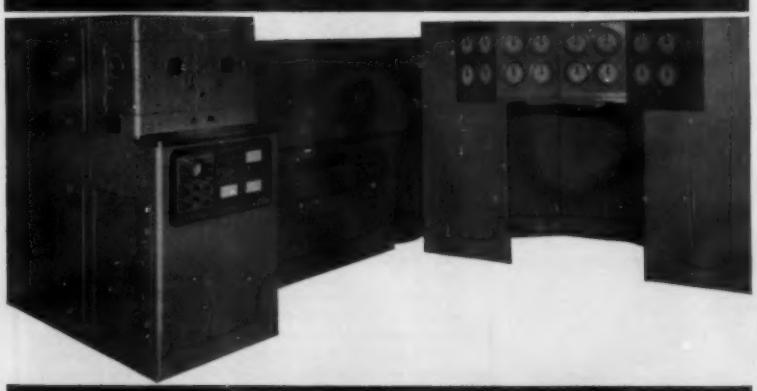

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Kinetics of Austenite Decomposition

Digest of "Isothermal Transformation of Austenite in High Speed Steel", by A. P. Gulyaev and K. A. Malinina, *Metallovedenie i Obrabotka Metallov* (Russian), No. 12, 1956. p. 2-8.

FOR WORKING OUT and improving heat treatments of toolsteels and high speed steels, it is essential to have information on the mode and kinetics of the decomposition of austenite. The present study was made to advance knowledge in this direction, and steel R 9 (0.9 C, 9.0 W, 4.3 Cr, 2.3 V) was chosen because of its wide application. However, the results obtained are applicable to other types of high speed steel. *(Continued on p. 184)*

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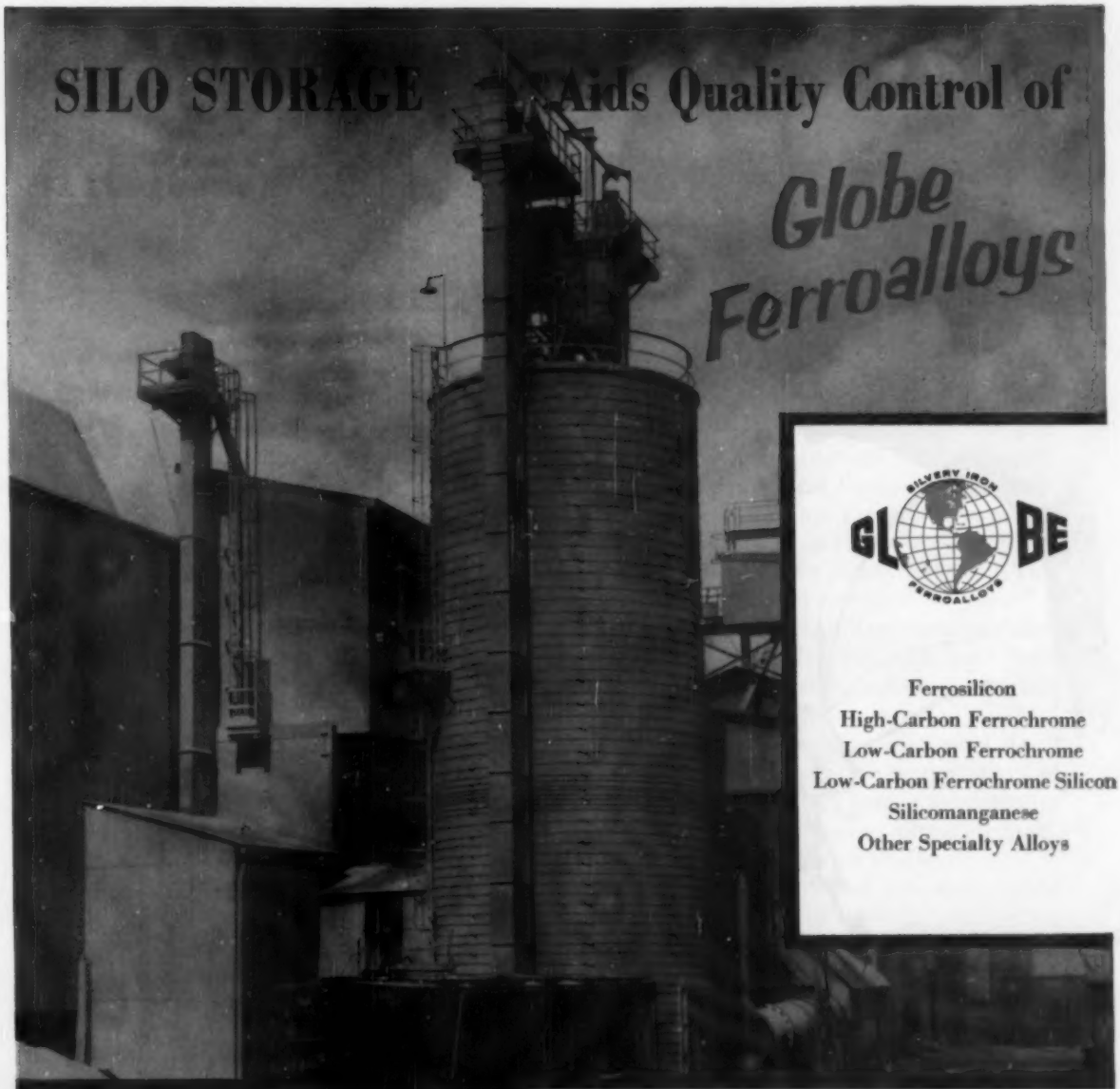

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levitation

ROBERT E. DROEGKAMP, senior engineer

Typical levitation of alloy specimen in a ceramic-coated, specially shaped, radio-frequency induction coil.

melting of uranium-base fuel alloys

Electromagnetic levitation with simultaneous melting, pioneered by Westinghouse in 1949, is being investigated at Bettis as a tool for melting research quantities of pure uranium-base fuel alloys. Reactive metals such as U, Ti, V, Zr, Nb, Ta, and Mo cannot now be melted in any of the known refractory materials and still retain sufficient purity for precise metallurgical investigations. To avoid crucible contamination, Robert E. Droegkamp, senior engineer, has been developing a levitation melting technique for application to nuclear fuel development.

Levitation melting offers several advantages: each melting charge can be prepared easily by compacting powders or chips of the material; the specimen does not touch a crucible during heating or melting; the alloy is thoroughly mixed electromagnetically before chill casting; volatile impurities can be removed; and the molten alloy can be protected by a suitable atmosphere or vacuum.

The force necessary to levitate a given material is a function of the size, shape, and resistivity of the material, the size and shape of the induction coil, and the frequency and amplitude of the alternating current used. The high density and resistivity of uranium alloys pose problems. Instantaneous superheating causes evaporation and ionization that result in a short circuit to the coil. This allows the metal to cast itself.

To date, specimens of a uranium-base alloy weighing about 8 grams each have been levitated in the molten condition for periods up to 5 seconds at pressures up to 1×10^{-5} mm Hg. When this technique is perfected, it will be possible to prepare uranium alloys of higher purity than previously available for transformation, corrosion, phase diagram, and possibly irradiation studies.

This levitation melting process described briefly is only one of the many challenging projects which metallurgists encounter at Bettis. We welcome confidential inquiries from metallurgists interested in the excellent careers offered by the expanding nuclear power industry. U. S. Citizenship required.

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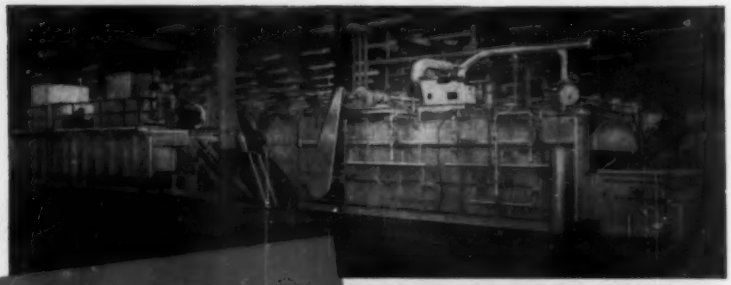

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Austenite . . .

To obtain isothermal transformation diagrams for various conditions of the austenite, the following types of heat treatments were used:

1. Austenitizing at 1650° F. followed by isothermal transformation for 5 hr. at various temperatures in the range from 1380° F. down to 212° F.

2. The same as (1) except that the austenitizing temperature was 2230° F.

3. Austenitizing at 2230° F., followed by cooling to 70° F., followed by isothermal treatments for 5 hr. at various temperatures in the range from 1380° F. down to 212° F.

4. The same as (3) except that cooling was continued down to −110° F.

5. Austenitizing at 2230° F., followed by cooling to 70° F., followed by heating at 1040° F. for 30 min., followed by isothermal treatments for 5 hr. at various temperatures in the range 930° F. down to 212° F.

6. The same as (5) except that the time at 1040° F. was 60 min.

7. The same as (5) except that the time at 1040° F. was 5 hr.

The austenitizing treatment at 1650° F. produced a structure containing 87% austenite and the balance carbides. The chemical composition of this austenite was 2.0 W, 2.9 Cr, and 0.3 V. Austenitizing at 2230° F. gave 96% austenite with a composition of 7.4 W, 4.2 Cr, and 1.4 V. When the austenite produced at 2230° F. was cooled to 70° F., 60% of it transformed to martensite. When cooling was continued down to −110° F., a total of 76% martensite was produced.

At the beginning of the various

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Austenite . . .

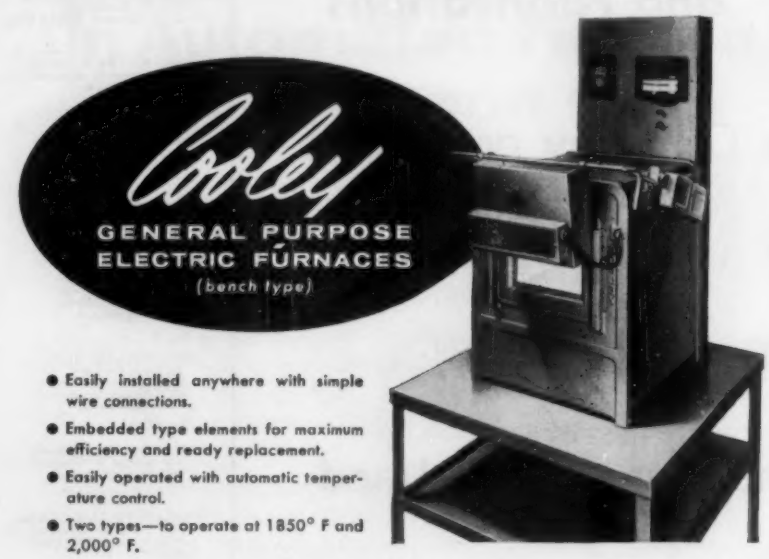
isothermal transformations listed above, there were the following percentages of carbide phases present in the microstructures: Treatment No. 3 contained 4.0%; No. 5, 4.4%; No. 6, 4.8%; and No. 7 treatment contained 5.8%.

Time-temperature-transformation diagrams were determined, using magnetic measurements to follow the transformation of the nonmagnetic austenite to its decomposition products, such as pearlite, all of which are magnetic. Results show that there are great differences among the transformation characteristics of primary austenite, retained austenite, and tempered retained austenite. On the basis of the experimental results, the following recommendations were made for improving various heat treatments of this steel:

1. For annealing after hot working: isothermal transformation at 1380° F. for 1 hr. followed by air cooling.

2. For annealing after welding: isothermal transformation of hot welded parts at 1380° F. for 6 hr., followed by cooling to 930° F., followed by air cooling.

3. For step quenching: isothermal treatment in a bath at 480° to 1110° F. for 5 to 10 min. A. G. Guy



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Smudge on Cold Rolled Sheet

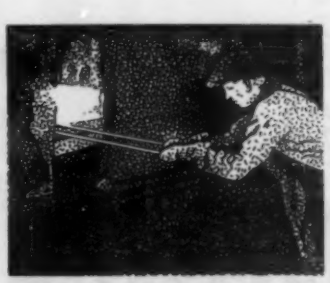
Digest of "Reducing Smudge on Cold Rolled Sheet", by Michael A. Matz, *Iron and Steel Engineer*, Vol. 34, April 1957, p. 105-106.

Mechanism of phase transformation of iron at the A_3 or upper critical point (about 1600° F.) during hot forming is believed to be intimately associated with the quantity of carbonaceous smudge appearing on cold rolled sheets. At the upper critical, atoms change from face-centered cubic to body-centered cubic lattice. Dissolved residual elements, present in virtually all commercial steels, have an inhibiting action on the transformation, giving rise to faults or fractures within the grain boundaries. Dissolved gases exert similar distortive effects.

Such discontinuities represent a weakened microstructure that is more susceptible to the attack of sulphuric acid in pickling, resulting in deeper pickling etches, more hydrogen embrittlement, and the carrying over of pickle-line contaminants on this overpickled surface. Because of the construction of modern pickling lines and rinsing cycles, these carryover compounds are never washed off entirely but are left on the surface of the coil as chemically active ferrous and ferric compounds. Upon coming into contact with the long-chain molecular formulas of rolling and precoating oil, many complex compounds are formed, principally carboxylates.

The deeply embedded pickle-line residues are forced to the surface during tandem rolling reduction and the heterogeneous mass, under the influence of friction, heat and pressure, tends to decompose the coating

(*Continued on p.* 188)



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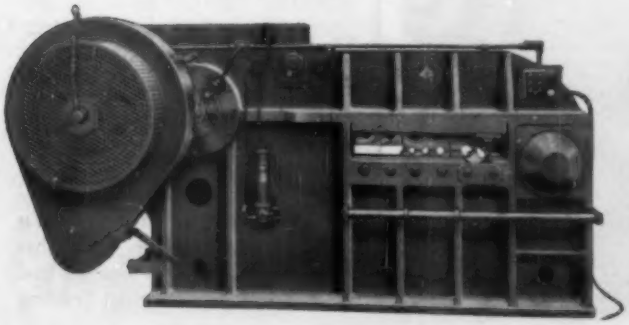

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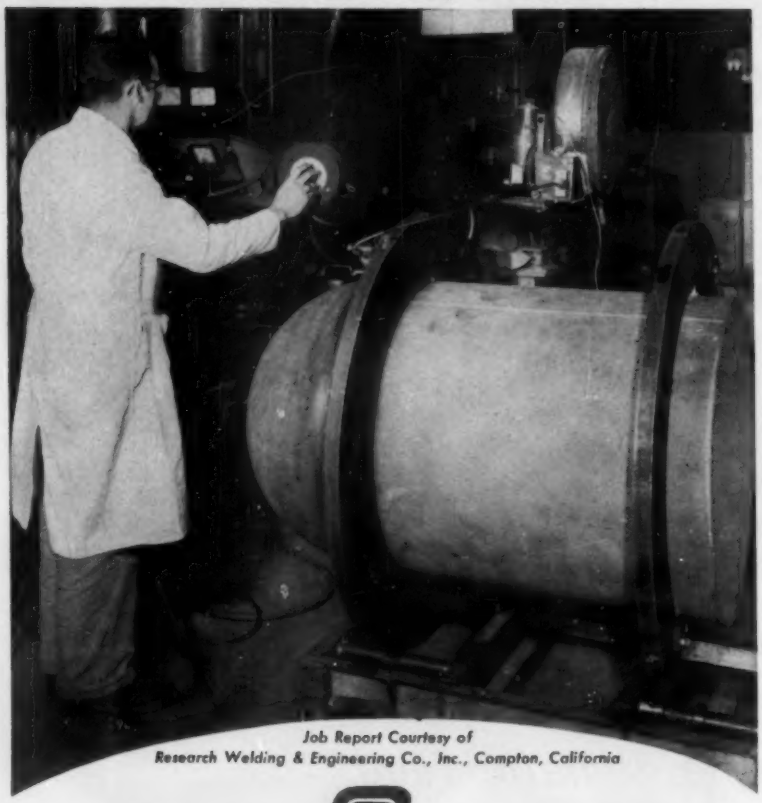

Job Report Courtesy of
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Light weight was important in this welded missile component that was required to hold air under 3,000 p.s.i. pressure. After making the root pass weld with the Arcos EB* consumable insert, the weld was completed by submerged arc welding with Arcos CHROMENAR CMV welding quality wire. CHROMENAR CMV was selected because its weld metal could be heat treated to match the base metal with tensile strength in excess of 200,000 p.s.i. and pass x-ray inspection. For help on your welding problems consult... ARCOS CORPORATION, 1500 S. 50th Street, Philadelphia 43, Pa.

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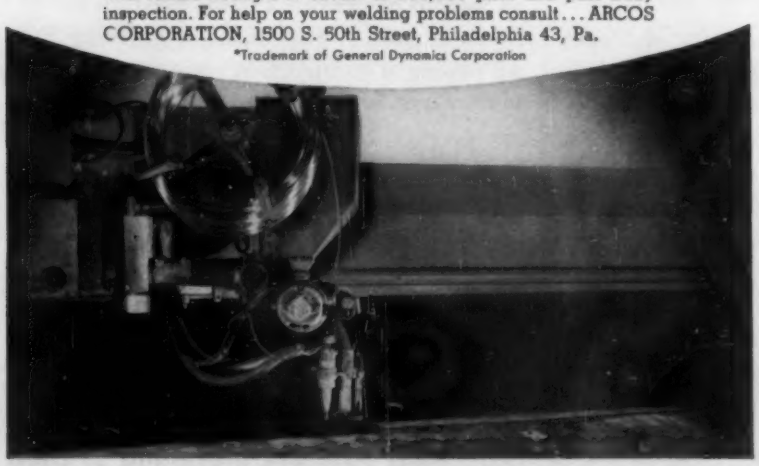

Smudge . . .

oil partially, resulting in deposition of amorphous carbon on the surface. Rolling oil is never totally emulsified, giving a sluggish mass which cannot be evaporated entirely during annealing. The end result is appearance of a black carbonaceous iron-bearing smudge on the sheet, either along the edges or over the entire surface, usually deeper when along the edges.

Skin passing or surface compacting prior to pickling is a valuable aid for producing a cleaner, less deeply etched surface.

Several recommendations are advanced to correct or minimize the smudge problem:

1. Temperature at which the steel is finished must be such as to allow minimum interference to the formation of the b.c.c. lattice at temperature below 1600° F.

2. Finishing and coiling temperatures must be correlated to produce an oxide film layer extremely rich in FeO, with minimum Fe_3O_4 and Fe_2O_3.

3. Present-day annealing practices using DX gas as the inert atmosphere are not conducive to the formation of uniformly bright coils, since a considerable amount of reduction and evaporation of surface contaminants cannot take place.

4. The most critical interval during annealing is in the range of 750 to 932° F. Within this interval, the oil must all be evaporated.

ARTHUR H. ALLEN

Forming Titanium Extrusions

Digest of "Forming of Titanium Extrusions", by I. J. Wilson, presented at Titanium Conference, Western Metal Congress March 1957. 9 p.

IN FORMING A-110 AT (91.5 Ti, 5 Al, 2.5 Sn) and 6 Al, 4V (89 Ti, 6 Al, 4V) extrusions, the author states that forming problems are essentially the same as those encountered in forming bars.

A major variable affecting the formability of titanium extrusions is the as-extruded surface, which has been very inconsistent. Longitudinal die marks seriously restrict bending

parallel to the grooves, frequently causing cracking. The oxide scale, which penetrates the surface to varying depths, is another source of cracking. These two conditions necessitate conditioning of extrusions before forming evaluation tests can be made. At present it is the practice at North American to machine all extrusion surfaces to a depth of 1/16 in. The author does not advocate machining as the final solution to the surface preparation problem since it is costly, time consuming and creates other problems, such as warpage. It is the best method, however, until acceptable as-extruded surfaces can be produced.

Having prepared an extrusion by surface machining, it is ready for forming tests. Stretch wrapping yields information on allowable stretch and shrink, and a practical picture of the sensitivity of the material to the optimum working range. It is, in a sense, analogous to uniform elongation and is a function of the elasticity and compressive strength of the material. A big problem in connection with this type of forming is the relatively narrow formability range of titanium, that is, the narrow spread between yield strength and ultimate. Furthermore, the range becomes narrower with increasing temperatures up to approximately 1250° F., and then the trend reverses itself and some improvement in formability is realized. Heating to temperatures of 600 to 700° F. may help if a reduced yield strength is required for machining purposes, provided the smaller formability range can be tolerated.

At present, for extrusions with machined surfaces, the allowable room-temperature bend has been set to limit stretch to 18% and shrink to 8%. Other combinations of stretch and shrink can be obtained under certain circumstances, but when the shrink exceeds a maximum figure, particularly in unmachined extrusions, brittle fracture and shattering may occur. Increased stretch, on the other hand, may cause the part to break in two pieces.

Beyond a certain value, increased rate of forming raises the yield and narrows the range. The potentials of high-speed forming in titanium are as yet unexplored.

In joggling, the runout is a func-

(*Continued on p.* 192)

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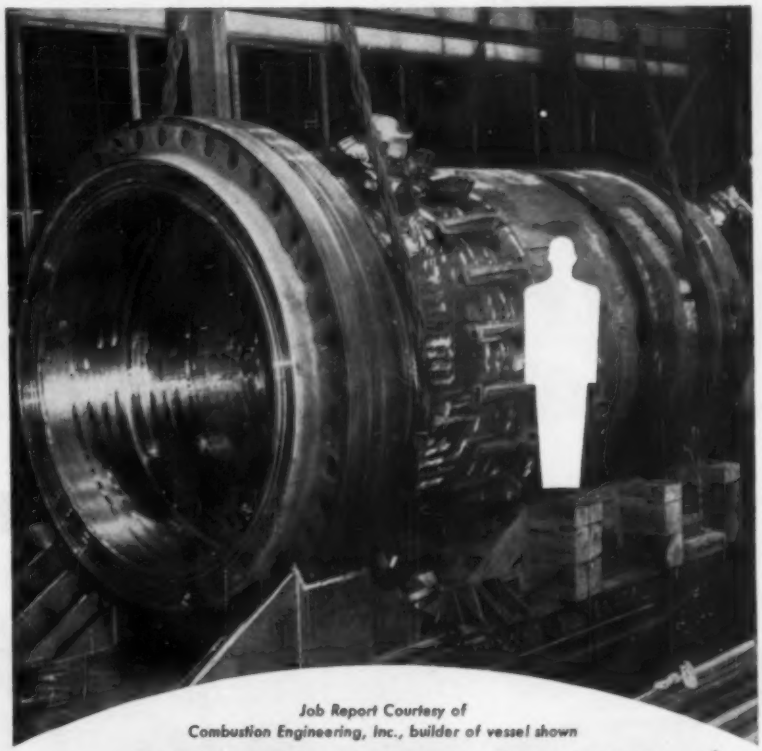

Job Report Courtesy of
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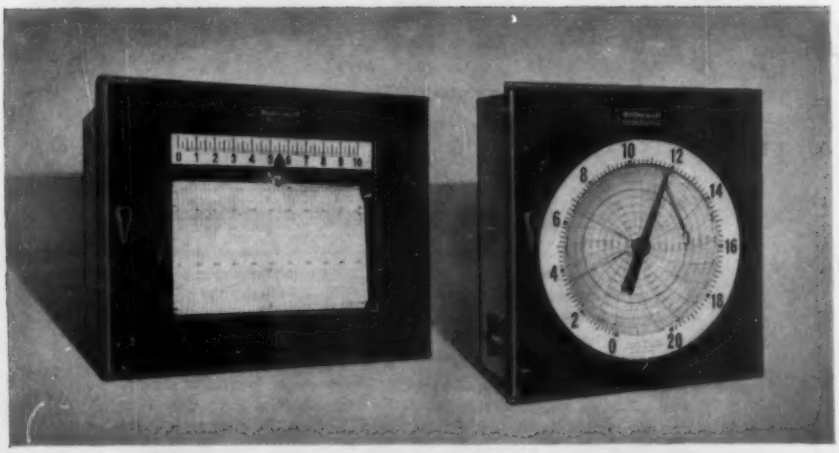

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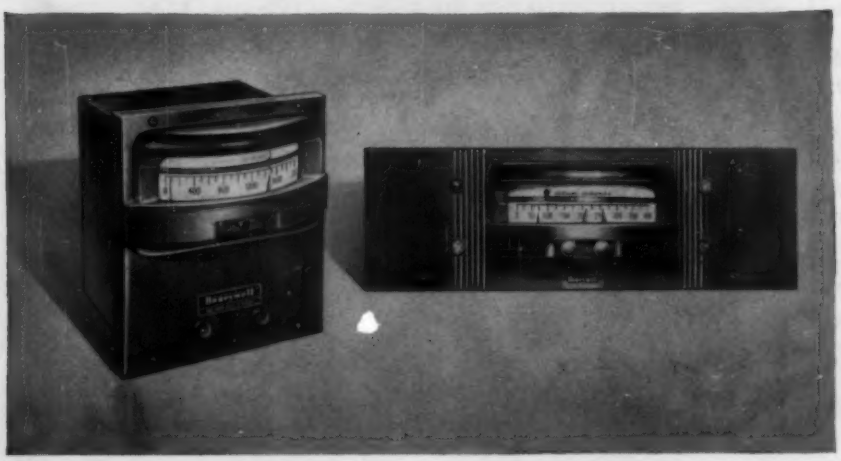

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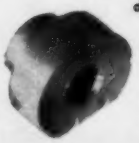

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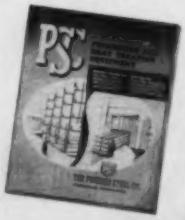

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Titanium Extrusions . . .

tion of the minimum bend radius and the ability of the material to flow in the runout area. As with stretch forming, proper surface condition is important in obtaining good joggles in titanium. Correct tooling, which prevents differential bending in extrusions with thick and thin sections, is also vital.

Although there are many problems, the author affirms that titanium extrusions can be successfully formed, by observing the following basic rules:

1. Take proper steps to secure a good surface condition.
2. Form at room temperature or above 1250° F.
3. Do not exceed the limited shrink and stretch allowables.
4. Use a generous bend radius.
5. Use good tooling.

W. V. WARD

Titanium Produced Electrolytically

Digest of "Preparation and Electrolysis of Titanium Trichloride", by H. N. Sinha and H. K. Worner, *Transactions*, Indian Institute of Metals, Vol. 9, 1955-56, p. 123-133.

THE ELECTROLYSIS of titanium trichloride in a fused salt bath is a promising method for producing titanium metal because continuous operation is possible, the consumption of energy is low, and the product can be kept reasonably free from oxygen. The trichloride can be prepared by reduction of the more readily available tetrachloride with reducing agents, such as aluminum, zinc, antimony, silver, hydrogen, and the alkali metals. Hydrogen appears to be most suitable because (*a*) it is obtainable relatively cheaply in large quantities and in a purified form, and (*b*) after the reduction, the hydrogen chloride formed, as well as any excess tetrachloride, is readily removed by distillation from the titanium trichloride powder.

Two reaction vessels were used; one (pyrex glass) produced titanium trichloride on a small scale, and another (stainless steel) produced batches of a few pounds. The base of the pyrex glass apparatus used for this process at the University of

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Titanium Production . . .

Melbourne in Australia was heated in a furnace to vaporize the charge of titanium tetrachloride in an atmosphere of hydrogen, and reduction to trichloride was brought about by electrically heating a tungsten filament in the upper part of the vessel to about 1830° F. A reflux condenser above the vessel prevented wastage of titanium compounds with the gases evolved. The solid trichloride collected in the bottom of the vessel and was removed in an inert atmosphere to prevent oxidation by air. The yield per hour was about 2.25 g. per sq.cm. of hot surface.

Using the same process, a larger stainless steel reactor vessel produced about 2 lb. of titanium trichloride in 12 hr. from 1.5 l. of titanium tetrachloride. In this reactor a 750-w. silica-sheathed tungsten filament was operated at 2010° F.

Another pyrex glass apparatus is described for combining the reduction of tetrachloride to trichloride, and the electrolysis of the latter to produce titanium metal. By this combination, oxidation of the reactive trichloride in handling is avoided. The apparatus consisted of three glass vessels, the first being a boiler to provide titanium tetrachloride vapor mixed with hydrogen. This mixture was led into the reduction reactor, equipped with a condenser and silica-sheathed tungsten filament as described above. The lower part of this reactor was connected by a glass tube to the lower part of the electrolytic cell. Both vessels shared a fused salt bath and the same furnace. The fused salt was the eutectic 60 mol per cent LiCl, 40 mol per cent KCl. The cell had a tungsten anode, and a tungsten cathode which was isolated in a special compartment, both extending downward into the fused salt.

All three vessels were provided with a hydrogen atmosphere, except during fusing of the salt, which was heated slowly to 1020° F. under hydrogen chloride to prevent hydrolysis from moisture in the

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salts. After the salts were fused, the electrolyzing current was checked but turned off again, until the trichloride production had proceeded for about 20 min. in the other vessel. Then electrolysis of the salt containing the trichloride was started. The current efficiency was 45 to 50% at an average current density of 50 amp. per sq.dm. After about 2 hr., the cathode compartment was removed and its contents tested after leaching with dilute hydrochloric acid, washing, and drying.

The metal powder produced was spongy and dendritic, and compared favorably with Kroll-process sponge in microhardness and lattice parameters by X-ray diffraction. Experiments are being continued to improve the coherency of the deposits.

G. F. Comstock

Hot Tearing of Magnesium Castings

Digest of "Hot Tearing of Magnesium Casting Alloys", by R. A. Dodd, W. A. Pollard and J. W. Meier, American Foundrymen's Society Preprint No. 57-43, 1957. 17 p.

Hot tearing is one of the more serious causes of defects in castings of complex design and of difficult composition. Thus, a knowledge of hot tearing characteristics is important.

In 1945, the Canadian Dept. of Mines and Technical Surveys began a fundamental study of the hot shortness sensitivity of magnesium casting alloys.

In the first phase, a simple hot tearing test was devised. The extreme hindrance to contraction caused by casting around too rigid cores (steel, in most of the test castings) tended to result in much solid state stress-cracking, particularly in those alloys containing brittle eutectic or other grain-boundary constituents. Also, the rate of cooling under these restrictive conditions was extremely rapid, and this effectively prevented healing of tears by liquid eutectic.

The second phase was concerned with the effect of chemical composition and constitution on hot tearing characteristics of binary magnesium alloys. The Singer-Jennings ring test

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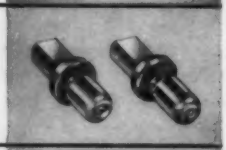

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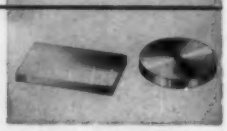

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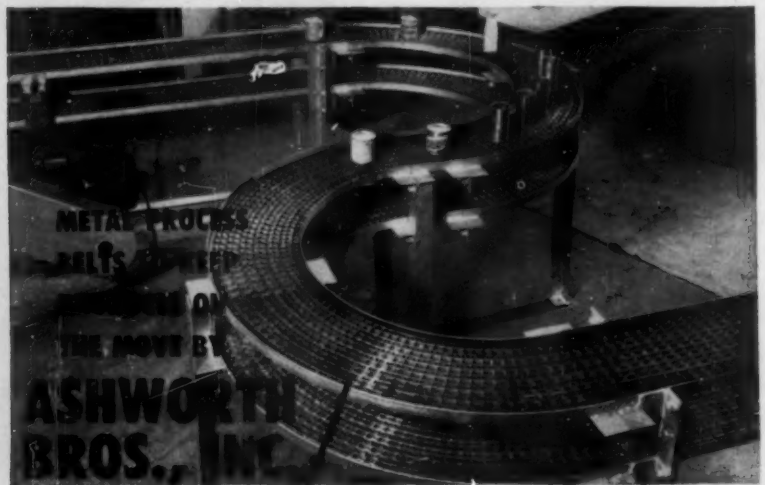

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Hot Tearing . . .

was used, and a classification was made of the susceptibility of commercial alloys to hot tearing.

The study confirmed that magnesium alloys are markedly less hot short than aluminum alloys of similar constitution, and that the performance of individual alloys is largely related to the solidification characteristics and the as-cast microstructure. The presence of a thin grain-boundary film suggests hot shortness, whereas thick films suggest a relatively tear resistant alloy.

In the third phase, a testing procedure was developed to evaluate commercial alloys and devise hot shortness sensitivity ratings.

Alloys containing rare earth elements were noticeably less susceptible to tearing than other compositions, and quite considerable eutectic crack healing took place, which was noticeable as bright ragged streaks on the otherwise matte casting surface.

With the aid of a modified test, made in all sand molds (no steel cores), the alloys were categorized broadly as (*a*) alloys having moderate to good hot tear resistance, for example, A10, EK30 and EM61, and (*b*) alloys having more pronounced hot shortness, such as M1, ZK61 and AZ31.

The conclusion is that sound castings can be produced in any of the alloys if proper care in casting design and molding procedure is taken. H. HEINE

Bonding Soft Metals to Semiconductors

Digest of "Technique for Connecting Electrical Leads to Semiconductors", by O. L. Anderson, H. Christensen, and P. Andreatch, *Journal of Applied Physics*, Vol. 28, August 1957, p. 923.

THIS PAPER describes a direct method of bonding various soft metals with clean single crystal semiconductor surfaces (germanium or silicon). The connection does not require chemical fluxes, intermediate materials, or vacuum environment. The physical phenomenon, adhesion without the formation of a liquid phase, is called a thermocompression

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A side view of the 72 cu. ft. Pangborn Rotoblast Barrel. Pangborn Barrels available in 1½, 3, 6, 12, 18, 20, 32, 72 and 102 cubic foot sizes

How do you build a giant blast cleaning barrel? If you're Pangborn, you use steel, inches thick. You put in the heaviest apron conveyor ever made. You incorporate the patented abrasive separator, abrasive-tight door, simplified Pangborn construction. You power it with two Rotoblast wheels that hurl *60 tons of abrasive an hour.*

Sure, it's tough to build . . . but it's worth it when you come up with a 72 cu. ft. Pangborn Rotoblast® Barrel! This unit cleans 6-ton loads *in five minutes* and gives the lowest operating and maintenance costs in the blast cleaning field! It's one of many Pangborn Rotoblast Machines. There's one for *your* problem.

The Pangborn Engineer in your area will be glad to take off his coat and go to work on your cleaning problem at no obligation. And for complete information on Rotoblast Barrels, write to: Pangborn Corp., *1800 Pangborn Blvd., Hagerstown, Md. Manufacturers of Blast Cleaning & Dust Control Equipment.*

Clean it fast with Pangborn ROTOBLAST®

See Pangborn at the Cleveland Foundry Show, May 19-23, Booths 2033-2037.

Bonding . . .

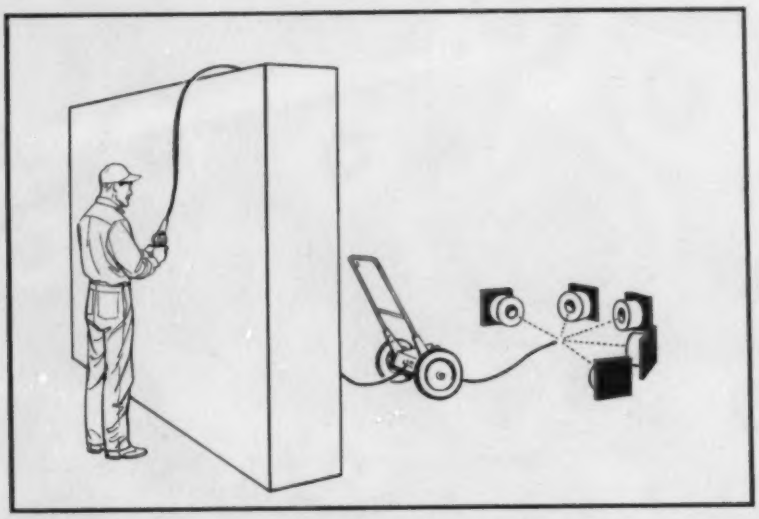
bond. Adhesion occurs in a time of seconds to a few minutes, at temperatures below the eutectic of the metal and semiconductor (as low as 300° F. below the eutectic) and pressures of the order of 5000 psi., provided that the metal and semiconductor both have relatively clean surfaces.

The equipment needed to make a bond consists of a heated element (shaped as a wedge, a flat, or a point) which presses the metal against the semiconductor. For example, a heated razor blade pressing a wire filament (0.0002 to 0.010 in.) against the semiconductor resting on a heater strip gives a practical bond. The metallic filament is annealed and cleaned in a flame or acid. Washing an etched surface of the semiconductor in water (or alcohol) is sufficient preparation for good adhesion. Another useful connection is made by butting the balled (or headed) end of a wire against the semiconductor by means of a capillary tube.

A certain pressure is necessary for the creation of a thermocompression bond. The authors consider it more practical to control the deformation of the metallic filament rather than the load. For strongest connection, the deformation of the filament under load should be kept within 10 to 30%. The bonding is distinguished from cold welding by the low pressure involved and the fact that one of the elements is very smooth and brittle. The required pressure for bonding is lower than that necessary to move or create dislocations in the semiconductor, as shown by etch pit counts near the bonded region. The strength of the connection is as strong as the filament. This rules out surface tension or secondary chemical bonding as the fundamental mechanism of adhesion. The authors have not been able to find any clear-cut microscopic or electrical evidence of diffusion of the metal into the semiconductor.

Pressures, temperatures, and time are reduced by either prior mechanical scrubbing of the surfaces, or outgassing of the surfaces prior to bonding in a vacuum. Wires of gold, copper, silver, and aluminum and a number of alloys of these metals can be bonded to either germanium or silicon. Gold wire to germanium is the easiest thermocompression bond attempted to date.

D.R.



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The quality control group of the Fort Pitt Steel Casting Division of Pittsburgh Steel Foundry Corporation, McKeesport, Pa., saves manpower, time and money by radiographing valve bodies with Nuclear Systems' Model 52 Multitron, a safe and versatile radiography machine.

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A DIVISION OF THE BUDD COMPANY, Philadelphia 32
Budd

Steel Cartridge Cases

Digest of "The Steel Case Program", by Philip H. Burdett, *Ordnance*, Vol. 41, July-August 1957, p. 195-197.

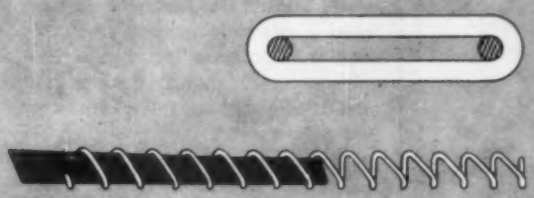
THE American Ordnance Small Arms Steel Case Committee (Dr. Burdett, chairman) has been concerned with the development of steel cartridge cases.

Solutions to metallurgical and surface finish problems frequently are uniquely applicable to one caliber or to ammunition for one type of gun and the solution to each must be sought separately. The characteristics of the particular gun, firing pres-

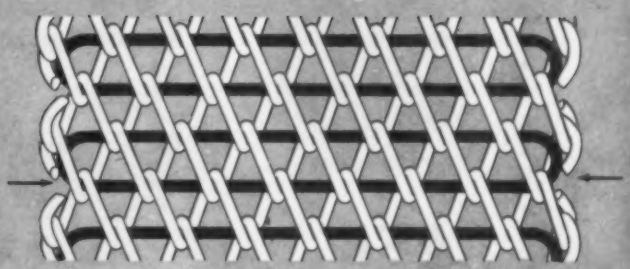
WISSCO BELTS

withstand high heat and carry heavy loads

Wissco High Temperature Belts have these exclusive construction features:

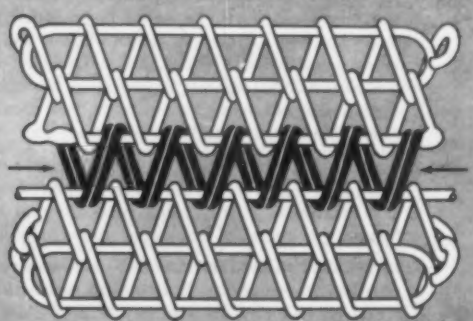


WISSCO'S EXCLUSIVE THIN FLAT SPIRAL is *formed* thin and stretch-resistant . . . provides a smooth supporting surface for heavy loads or tall, slender objects . . . distributes the wear over a large area.



WISSCO'S DUAL CONTINUOUS REINFORCING ROD — Two adjacent rods are joined to form a flattened oval. The extremities of this oval are located inside the knuckled edges of the belt to give full reinforcement and prevent narrowing of the belt.

PERMANENT "FREE" KNUCKLING — An opening, equal to the diameter of the reinforcing rod, is left between knuckle loops. Since there is no load on knuckles they cannot pull open and cause ragged edges.



WISSCO'S EXCLUSIVE QUICK SPLICE CONNECTOR — One end of each Wissco Belt is fitted with a double spiral of the opposite hand weave to that of the belt. A single straight rod is inserted through the loops of section ends and held in place by knuckling or welding.

Our engineers have long experience working with leading manufacturers on their high temperature process-conveying problems. Many have shifted to Wissco Belts and are getting longer service life, less down time and greater production. Why not let us show you what a Wissco Belt can do for *you*?

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Cartridge Cases . . .

sure and rate of fire are some of the determining factors.

Progress on steel cases during the past seven years has been slow but solid. Some work has been performed with each of the military small-arms calibers. In no instance does there appear to be any real obstacle to the manufacture of a satisfactory steel case. What is needed most is experience, not only in manufacture of the cases, but also in refining and rolling the steel.

There has developed a somewhat conflicting climate of opinion on this whole small case program. Some military planners believe that the steel case program is not of critical importance; that brass cases are adequate; and that in time of emergency brass will be available in unlimited quantities. Others believe that with modern high-cycle rate guns and high firing pressures only steel will produce adequately strong cartridge cases. The Assistant Secretary of Defense for Engineering has issued a strongly worded warning concerning the necessity for conservation of materials and has cited the use of steel for cartridge cases as an example of what can be done. The American Ordnance Assoc. favors continued support of the small-arms steel case program, proposing the manufacture of noncombat small-arms cartridge cases from steel within the limits of available know-how. Their proposal includes practice rounds, dummy cartridges, and blank cartridges. They caution that extensive production experience is needed before reaching any definite conclusions.

The caliber 0.30 program is being carried out on a limited scale. The 7.62-mm. NATO program awaits weapon standardization. It is hoped to produce either case on interchangeable lines using unoriented heat treating and barrel plating equipment. Only fully hardened and tempered cases are acceptable. Production-type equipment for oriented heat treatment and quench is still in the development stage of manufacture. The only acceptable finish to date is chromated zinc electroplate. No practical way has yet been found to apply epoxy-phenolic varnish, an otherwise acceptable finish.

FRED M. ARNOLD

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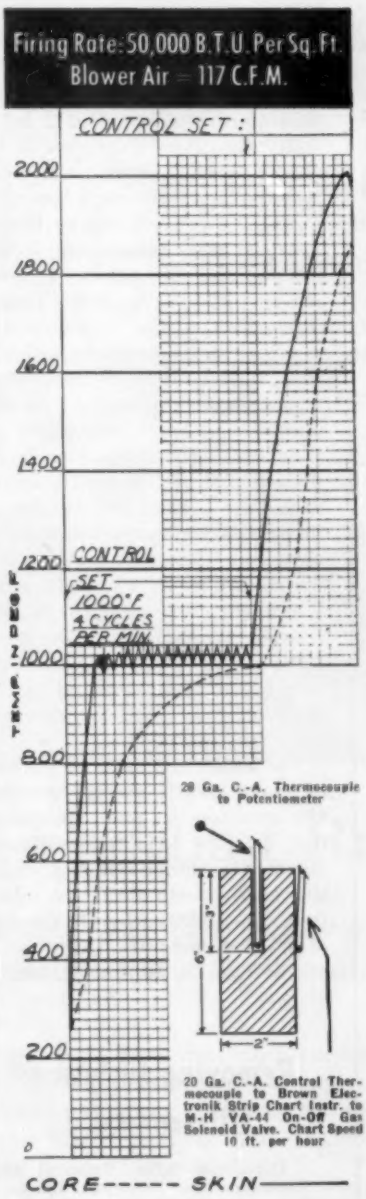

Heating Instantly

Holden Luminous Wall firing system is a method of uniformly applying instantaneous heat to parts in process.

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Thermal storage in refractory lining is eliminated. A positive source of radiation, transferring maximum amount of heat directly to the work with negligible thermal storage in furnace structure. This means rapid starting, cooling and re-starting.

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Typical example of rapid heating shown on graph. From a *cold start* and firing 50,000 BTU per sq. ft. following temperatures were obtained:—

1. Up to 1000° F. (10 min. lag 800° to 1000° F.)
2. Up to 1975° F. (3 min. lag)
3. 1975° F. to 2275° F. (3 min. lag)

The refractory wall has no heat storage so conversely, when gas is shut off and air allowed to blow through furnace wall, the wall immediately assumes temperature of incoming ambient air.

Advantages

Luminous Wall—Instantaneous Heating offers—

1. Greater overall heating efficiency—more than any other type gas furnace.
2. 40% less fuel consumption per average day
3. Rapid furnace heating—From a cold start, temperatures of 1000° to 2000° F. obtained within time cycle of 1 to 10 min. using 50,000 BTU per sq. ft.
4. Rapid furnace cooling—no refractory spalling
5. Increased refractory life—Tests conducted in unit over 3 years old operated at temperatures to 2300° F. without refractory replacement

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Mechanism of Sintering Aluminum Oxide

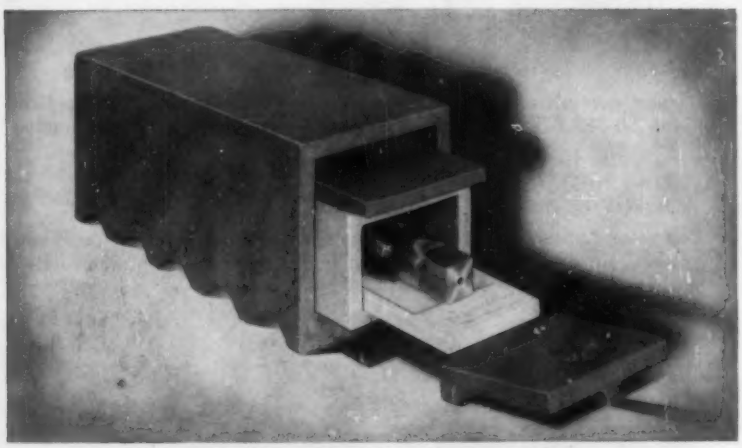
Digest of "Role of Grain Boundaries in Sintering", by J. E. Burke, *Journal* American Ceramic Society, Vol. 40, March 1957, p. 80-85.

OUR UNDERSTANDING of the sintering mechanism has progressed quite rapidly; perhaps because of the diversity of experimental methods applied, and because studies have been made not only with metallic powders, but also with oxides, carbides, and glass beads. In the present paper, a metallurgist has studied the sintering of aluminum oxide, which is traditionally a problem in ceramics. The problem is approached from a metallurgist's point of view, and the excellent results show what can be achieved when the traditional barriers between metals and nonmetals are removed and the problems of solid materials are considered in their broadest aspect.

Aluminum oxide was chosen since it is an ionic compound obtained with a relatively high degree of purity. The author observed changes in pore size, pore distribution, and the interaction between pores and grain boundaries during the process of sintering. The alumina powder was 15 μ in size. After sintering for one hour at 1800° C. (3270° F.), the pores, resulting from the misfit between particles, showed even distribution between the grains. After sintering for one hour at 1900° C. (3450° F.) recrystallization took place and the average grain size was about 300 μ. At this stage, practically all the pores were located inside the grains. The average porosity remained about the same, as shown by the absence of shrinkage. After further sintering of 2 hr. at 1950° C. (3540° F.), some of the pores became larger, many disappeared and there was a noticeable absence of pores in regions located near the grain boundaries. It was evident, therefore, that the pores disappeared faster near grain boundaries than in the center of the grains. This observation confirmed those made by previous investigators in the sintering of copper. In alumina, as in copper, the reason for shrinkage of pores cannot be due to the action of surface tension accompanied by plastic flow, because if that were so, all pores would shrink uniformly. It is more probable that the mechanism of sintering is a diffusion one, as described by the Nabarro-Herring model. The atoms diffuse from grain boundaries to neighboring pores, and the grains move together to fill the vacancies left by the missing atoms.

The author also discusses the role of grain growth during sintering. His evidence is quite convincing that in order to obtain maximum densification during sintering, excessive grain growth should be inhibited. The addition of small amounts of selected impurities might be a practical answer to this problem.

POL DUWEZ



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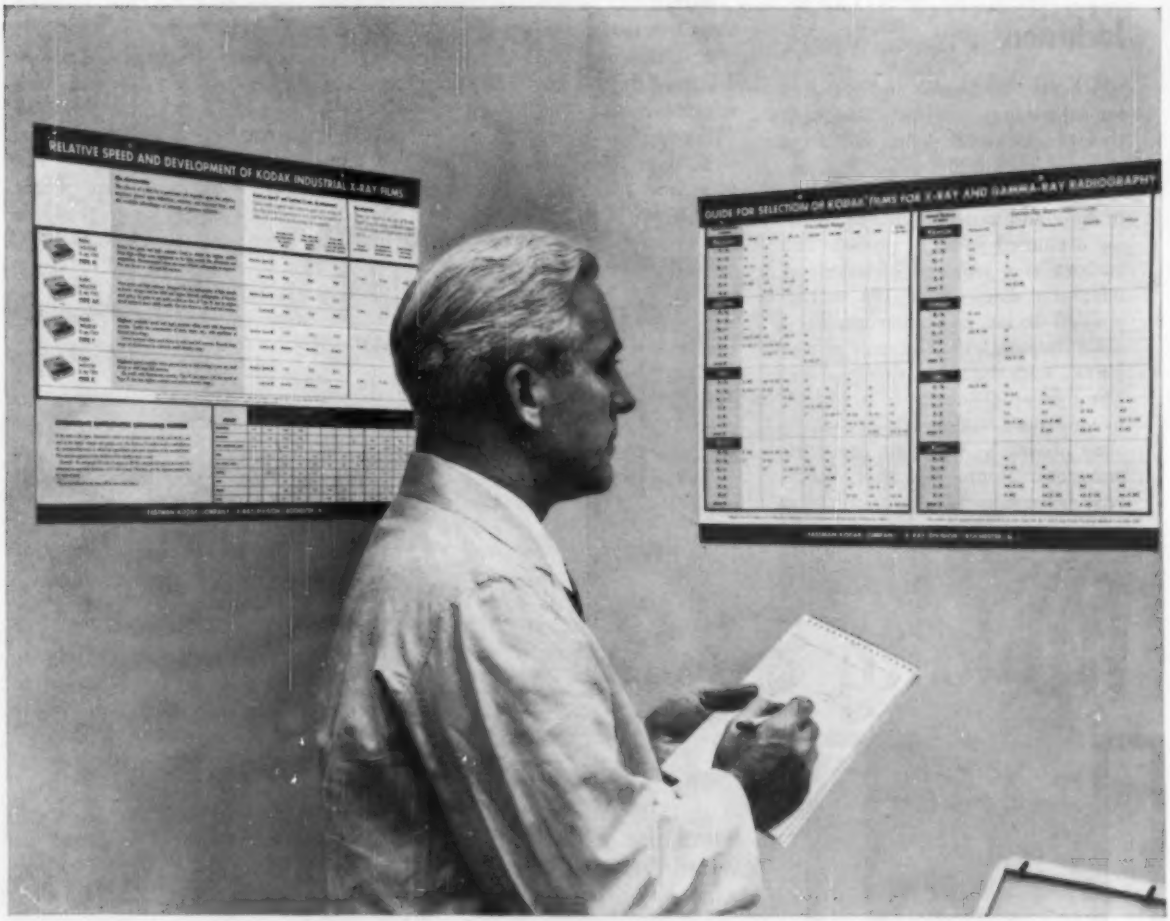
Removing Inclusions Ultrasonically

Digest of "The Removal of Inclusions for Analysis by an Ultrasonic 'Jack Hammer' ", by George L. Kehl, Hyman Steinmetz and Warren J. McGonnagle, *Metallurgia*, Vol. 55, March 1957, p. 151-154.

SMALL INCLUSION particles in metals have to be extracted either chemically or mechanically before they can be identified. Reagents with selective dissolution properties make it possible to attack the matrix metal and leave the included material as loose debris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GUIDE FOR SELECTION OF KODAK FILMS FOR X-RAY AND GAMMA-RAY RADIOGRAPHY

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TODAY'S fast films and varied radiation sources give the present-day radiographer many new opportunities for establishing exposure factors to meet unusual conditions and get better radiographs.

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Inclusions . . .

which may be filtered and gathered for subsequent analysis. Danger is that the inclusion debris will have changed chemically.

Manually, removal is confined to probing and loosening inclusions using a pointed stylus or probe. The authors have removed inclusions of minimum diameter of 10μ with a pointed stylus oscillating at ultrasonic frequencies. The work is performed with the aid of a microscope. The method is ideally suited to removing hard and brittle secondary alloy phases, as well as nonmetallic inclusions of either the hard, glassy type or loose, fluffy varieties.

Extraction apparatus includes these five major components:

1. Ultrasonic driving oscillator matching the natural frequency of a selected barium titanate transducer (47 kc. per sec.).

2. Brass horn cemented to the transducer to magnify linear motion by a factor of about 30.

3. Pointed stylus making contact with the inclusion to be removed.

4. Bench-type metallurgical microscope with glass hood over the specimen holder to permit inert gas shielding of specimen if necessary to prevent oxidation of debris.

5. Two micropositioners, one to hold the transducer horn assembly and to locate the stylus precisely, the other to manipulate a greased quartz fiber to gather up the inclusion debris after extraction.

At the outset, stylus points were made from 0.02-in. diameter tungsten wire, electrolytically pointed; but its relative softness, short life as a tool and loss of tungsten during use, thereby contaminating debris, dictated a change to 0.045-in. diameter carbon steel drill rod heat treated to maximum hardness.

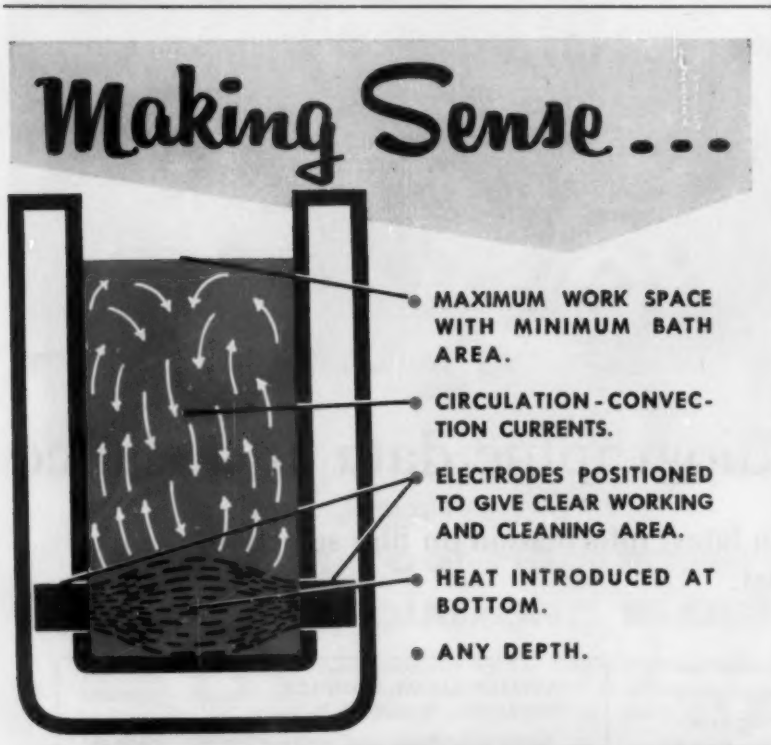
Preparation of Stylus – The drill rod is pointed electrolytically by controlled immersion in a solution of 50% glacial acetic acid and 50% nitric acid, cooled during use by an ice bath or by addition of dry ice chips. The drill rod serves as one electrode, suspended vertically in the electrolyte from the stage of a micropositioner. A strip of platinum foil is the other electrode. With electrodes connected across 8 to 12 v.a-c., the end of the drill rod is immersed to a depth of about ⅜ in. by actuating the positioner, and then withdrawing on a cycle of about 2 sec. After 25 to 30 cycles, the end becomes pointed, but still not sufficiently sharp. Final pointing calls for immersion and withdrawal at a constant rate until current is reduced to 0.2 amp. Then the wire is left in the electrolyte until current drops to zero, after which it is withdrawn immediately.

After pointing, the rod is cut to a 2½-in. length and attached to the horn by inserting into a drilled hole and fixing in position with softened hard wax.

Extraction Procedure – Area of interest on the specimen is located microscopically and the vibrating stylus is lowered until contact with the inclusion is made. Thereupon the inclusion is shattered locally and a shower of debris is formed and scattered in the vicinity. Depth of penetration and size of the resulting cavity in the inclusion are controlled by manipulation of the stylus through the micropositioner.

When sufficient inclusion debris has been created, usually after 15 to 20 min. of this action, fragments are gathered on a quartz or glass fiber suitably coated with grease or an adhesive and then transferred to X-ray diffraction apparatus for analysis. Photomicrographs show the effectiveness and precision of this method of extraction.

ARTHUR H. ALLEN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With installation of our new electric furnace, we at Standard are now equipped to give you even better service—even faster deliveries—and much greater variety of steel analyses—than ever before.

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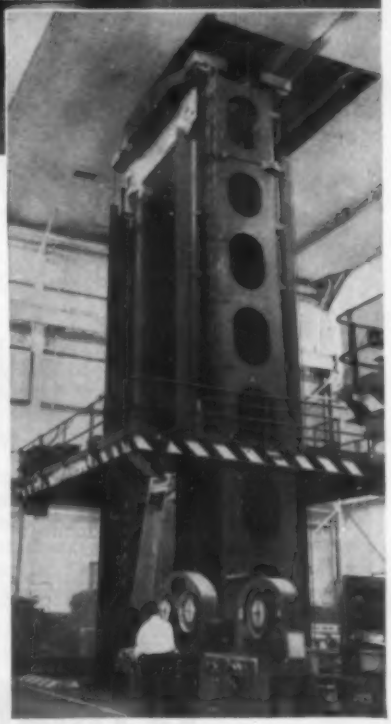
Rings • Shafts • Car wheels • Gear blanks • Flanges • Special shapes

The specimen under compression test is laminated timber, 10 ft. in length and 30 in. square. Failure occurred at 4,840,000 lb.



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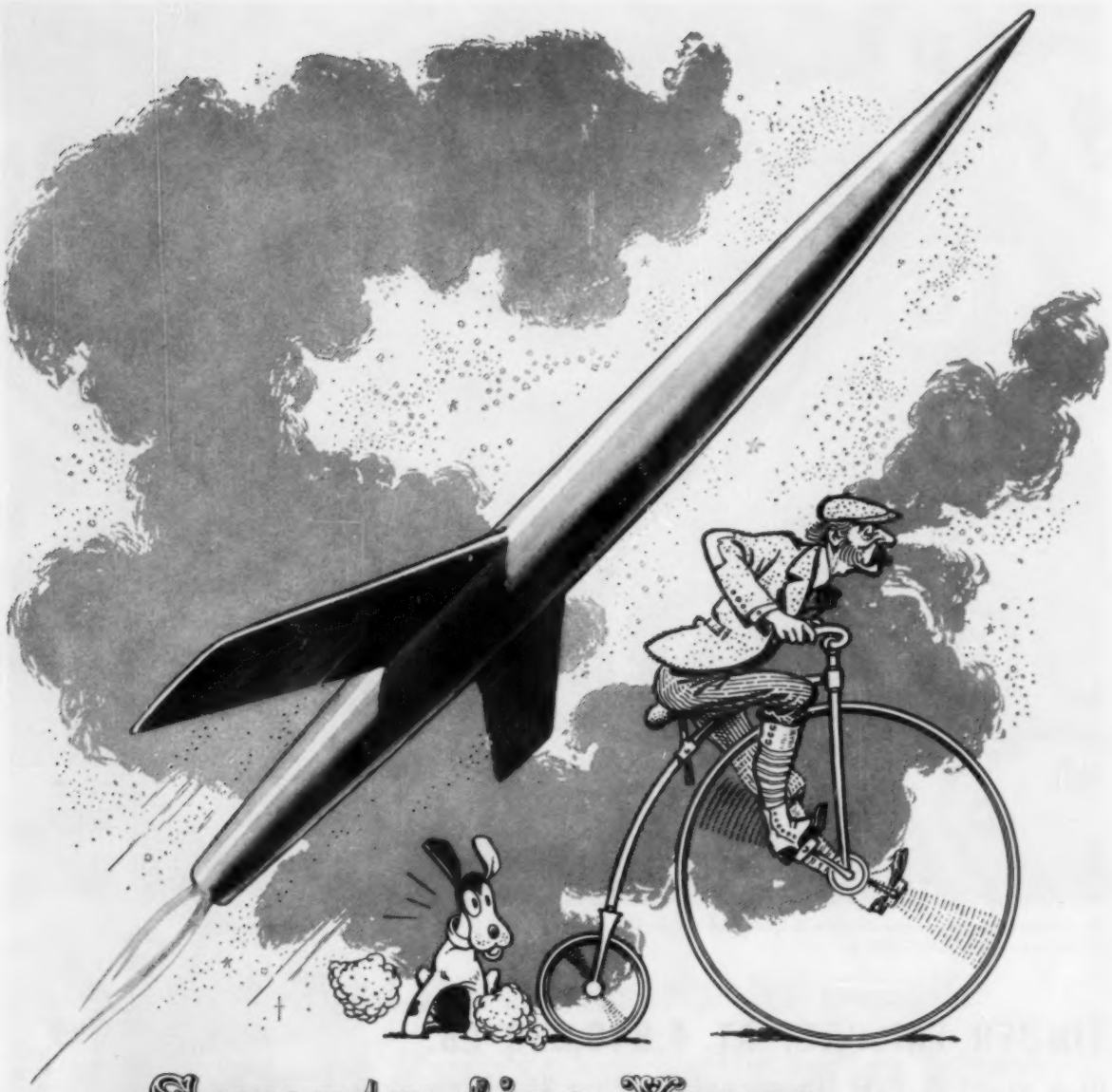

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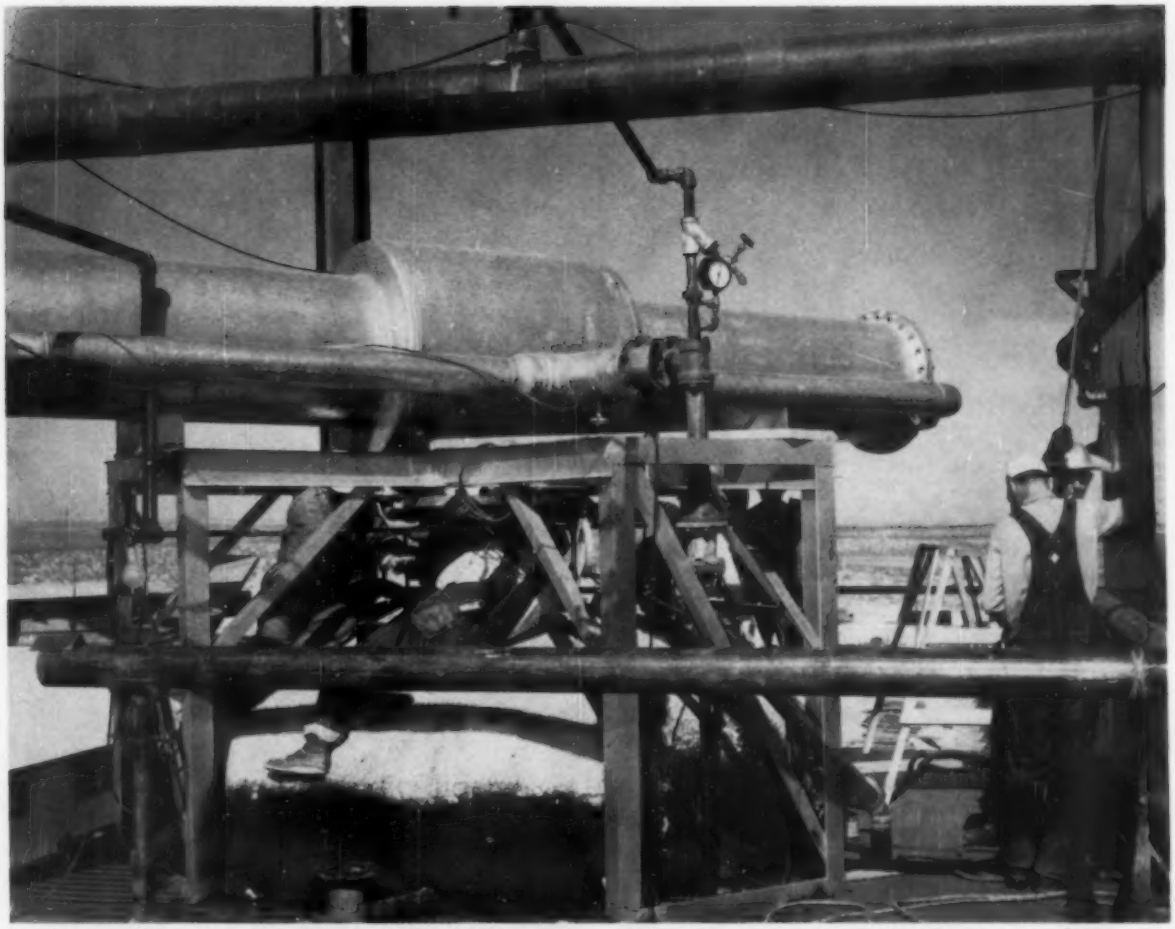

Erecting a crystallizer at a potash refinery in Carlsbad, N. M., operated by Pacific Coast Borax & Potash Co. This is one of seven crystallizers that were shop- and field-fabricated, then field-assembled by welding. They were not stress-relieved or heat-treated. There has been no stress-cracking in the nine months these units have been in service at the potash refinery.

NEW Ampco Metal Grade 8 stops stress corrosion cracking!

Important changes have been made in Ampco Metal Grade 8! It's *entirely new*—and completely obsoletes old ideas about fabricating copper-base alloy equipment to handle steam and corrosive media at elevated temperatures.

Now, with new, patented Ampco Metal Grade 8, you can . . .

1. Field-fabricate *without stress-relieving!*
2. Make field repairs, changes, and alterations *without heat treatments!*
3. Readily weld with any electric welding process! A. No pre-heat. B. No post-heat. C. No hot-short cracking!

At one major oil refinery, field-assembled piping of Ampco Metal Grade 8 has handled hot sulphuric-acid sludge for a year and a half without stress-cracking. Driers in a paper mill have handled 350° F steam at 125-lbs. pressure for more than a year without stress-cracking.

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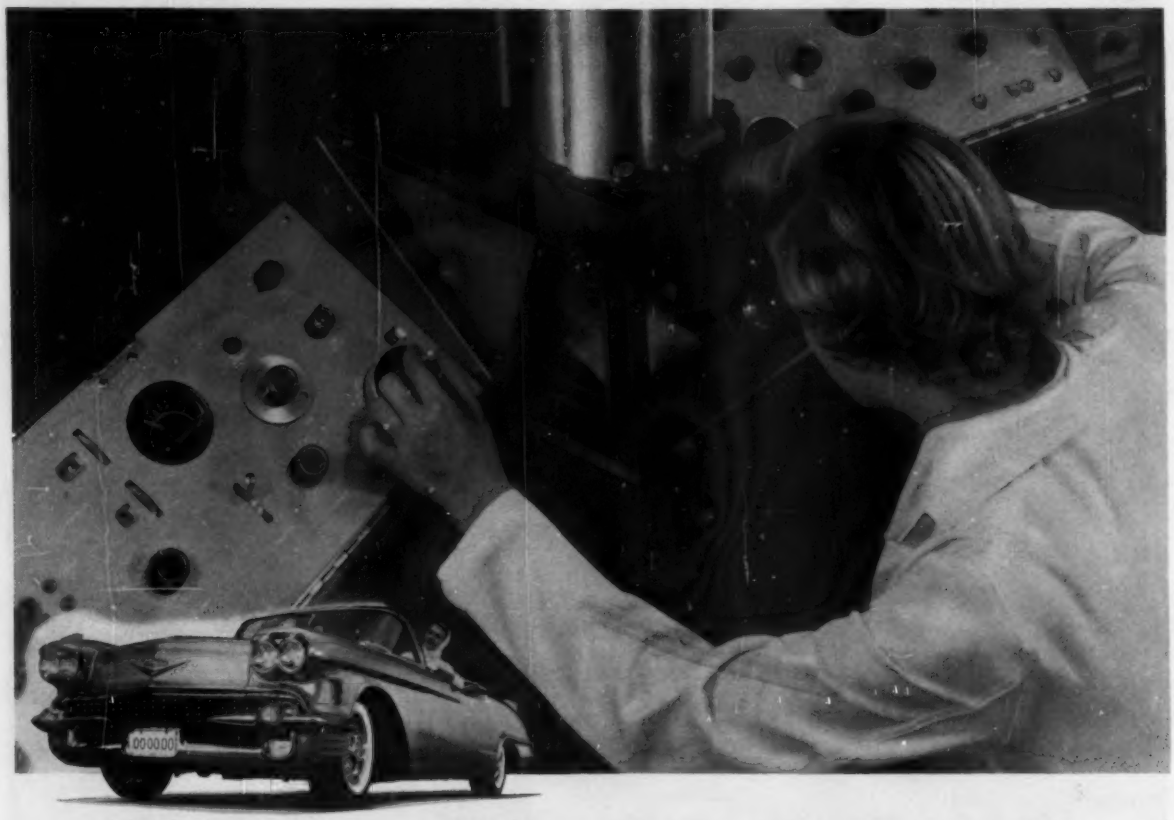
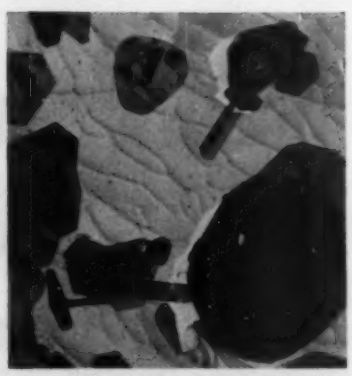


RCA Electron Microscope helps build better cars at General Motors

Automotive masterpieces have virtues that are more than "skin deep," thanks to basic research with the RCA Electron Microscope. At General Motors Technical Center in Detroit, studies using the instrument range in scope from determining deformation in crystalline solids to quality control problems in connection with heat-treated metals. Recently, GM researchers correlated the score resistance properties of an alloy used in bearings with the precipitation of silicon.

Micrographs, such as shown, indicated that optimum performance resulted when the aluminum-silicon-cadmium-bearing material was heat treated to precipitate the thin crystallites of silicon throughout the matrix. Particle size and distribution were studied by means of electron microscopy and positively identified by electron diffraction.

RCA Electron Microscopes are providing valuable information regarding size, shape and structure of particles smaller than 20 angstrom units. With the ability to produce direct electron image magnifications up to 200,000X, the RCA Electron Microscope is advancing man's knowledge in many fields, as diversified as automobiles and cell structures . . . chemicals and viruses. Installation supervision and contract service are available through the RCA Service Company.



Undissolved silicon (large opaque particles) and thin silicon plates in an aluminum matrix, magnification 12,000 diameters. (Micrograph courtesy General Motors Research Staff.)

For full particulars, write to RCA, Dept. F-72, Building 15-1, Camden, N.J.
In Canada: RCA VICTOR Company Limited, Montreal.

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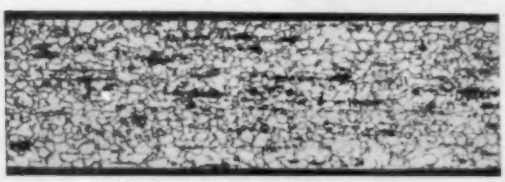
CAMDEN, N. J.

Uniform fine grain, improved drawability with Selas short-cycle continuous strip annealing

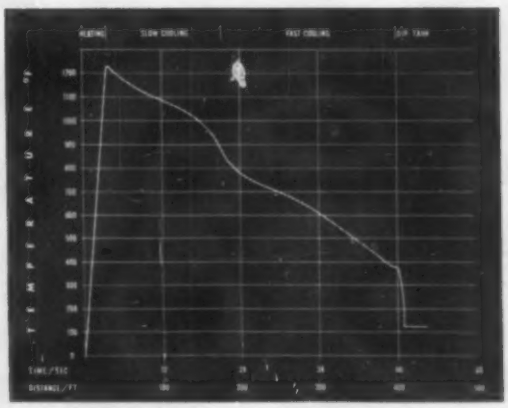
THE AIM OF Selas short-cycle annealing is to soften the material by recrystallizing ferrite grain structure which has been distorted by previous cold working. Tinplate, for instance, is heated to 1200°F-1300°F, a temperature above the recrystallization temperature (about 1050°F) but below the lower critical transformation temperature (about 1330°F). All of the heating is accomplished in a single-pass, vertical furnace. The exposed time is about 3.6 seconds, representing approximately 30 feet of effective heating furnace when the strip is run at 500 fpm.

Extremely short time under heat produces the desired results: heating is so rapid that the strip is well above recrystallization temperature before nucleation of the recrystallized grains begins. A large number of these nuclei are then formed almost simultaneously so that recrystallization is complete before individual unstrained grains can grow to any size.



Photomicrograph of short-cycle annealed product, 100X

In conventional annealing, batch or continuous, strip is held at temperature in order to produce completely recrystallized structure. The Selas strip-heating principle involves no holding or soaking period since strip leaves the short-cycle furnace at a temperature uniform from edge to edge throughout its full length. Cooling is retarded somewhat to 900°F to permit precipitation of the carbon dissolved at annealing temperature; then the strip is cooled as fast as may be practical.



Strip temperature in heating and cooling sections

At this point the product is fully annealed, although it is stiffer—and stronger—than batch-annealed tinplate. It can be drawn as well or better than batch-annealed strip. It has uniform grain structure and uniform high corrosion resistance.

This combination of stiffness and drawability is characterized as universal temper—designated TU. The fact that the strip is both stiff and drawable makes possible the use of lighter gauge material.

Since recrystallization is similar in other metals, it is reasonable to expect that other strip metals might also benefit from short-cycle continuous annealing. This has been confirmed by production annealing of brass and stainless steel and by test runs on other metals.

You are invited to send for the paper "Continuous Annealing Sixty Tons per Hour of Tin Mill Products." Address Dept. 35, Selas Corporation of America, Dresher, Pennsylvania.

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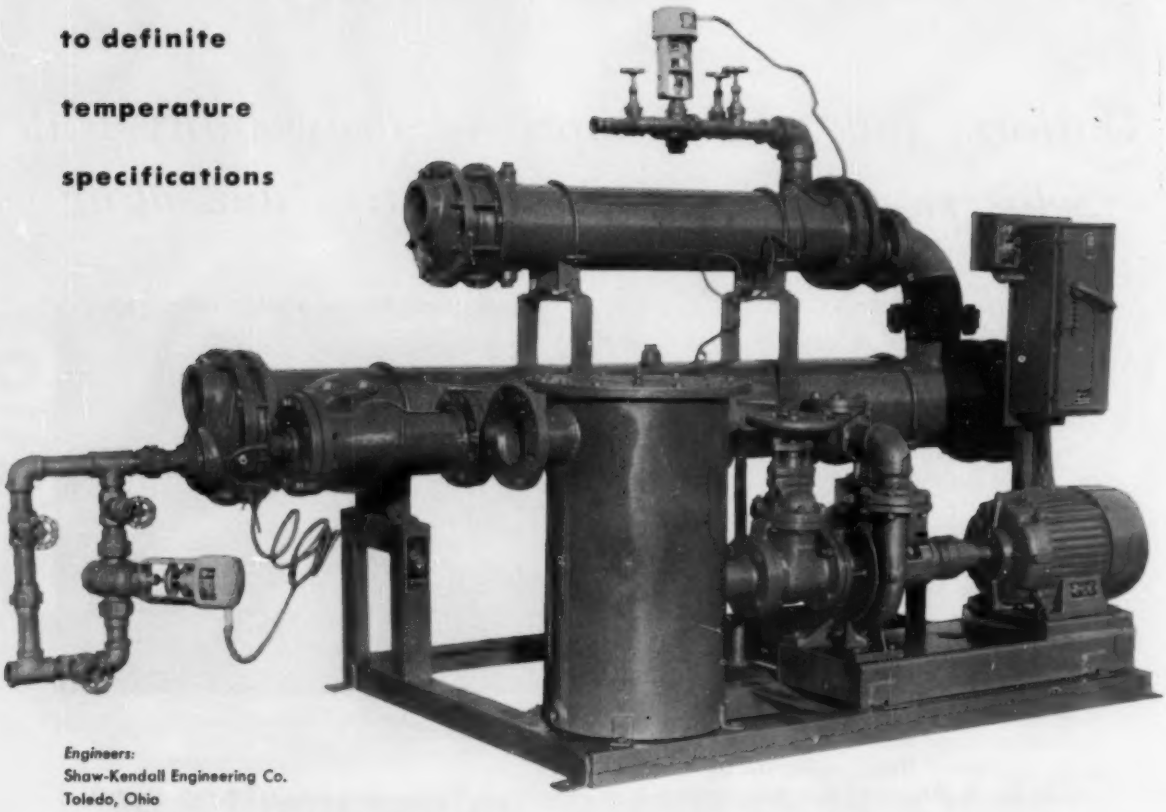

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At the Chevrolet Motor Division of General Motors Corporation, Toledo, Ohio, this B&G Self-contained Quench Oil unit performs a double duty in controlling quench oil temperatures.

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			Rm. 70°	Rm. 110°	L	W	H	L	W	H
Sub-Zero	SZH153	1.5	–95° F.	–85° F.	42"	28"	42¾"	23"	9"	12½"
Sub-Zero	SZH653	6.5	–85° F.	–75° F.	60"	28"	42¾"	47"	15"	16"
Sub-Zero	SZHC657	6.5	–140° F.	–125° F.	60"	28"	42¾"	47"	15"	16"
Rivet Cooler	RSZ503	5.0	–30° F.	–20° F.	42"	28"	41"	30"	16"	18"

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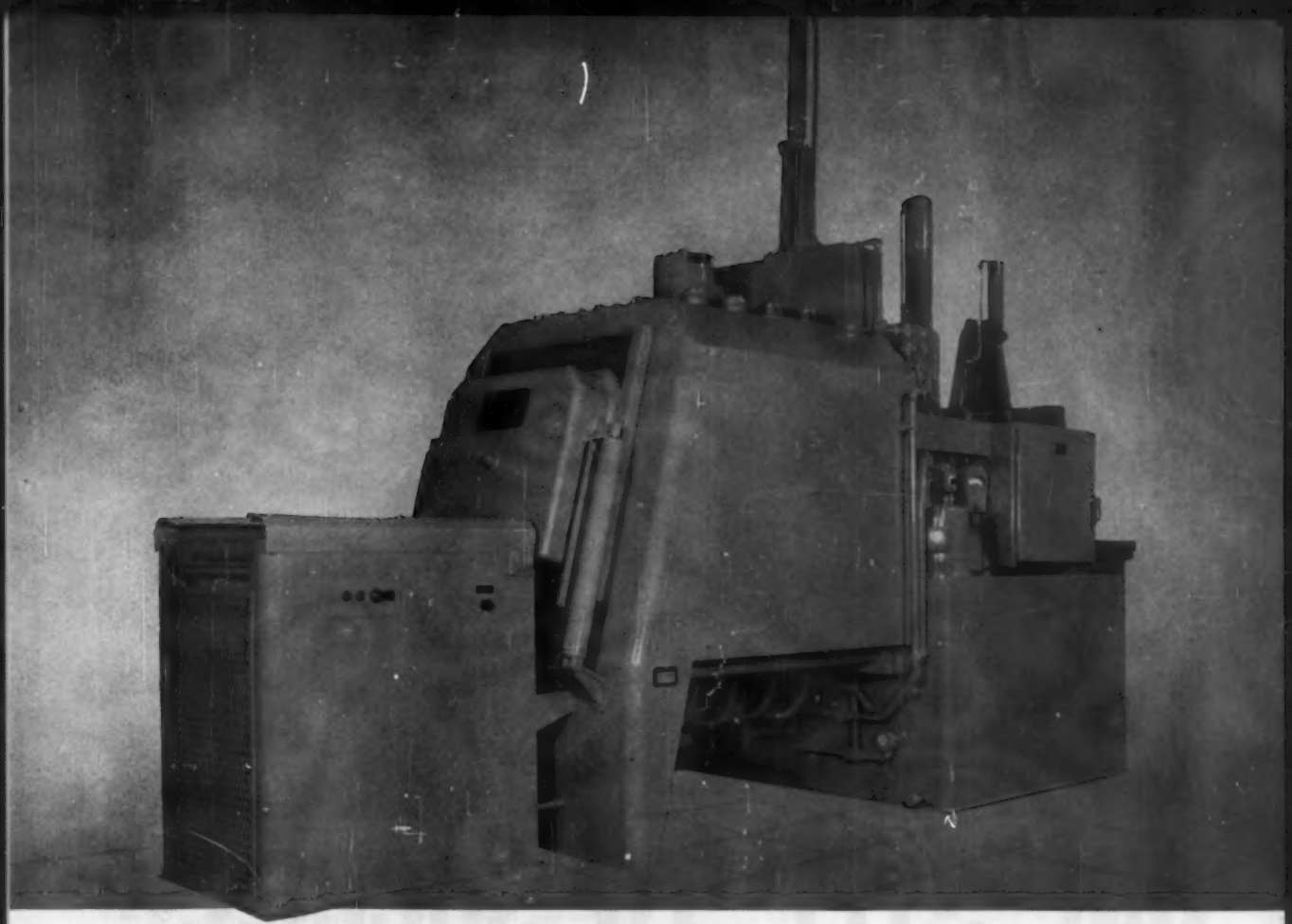

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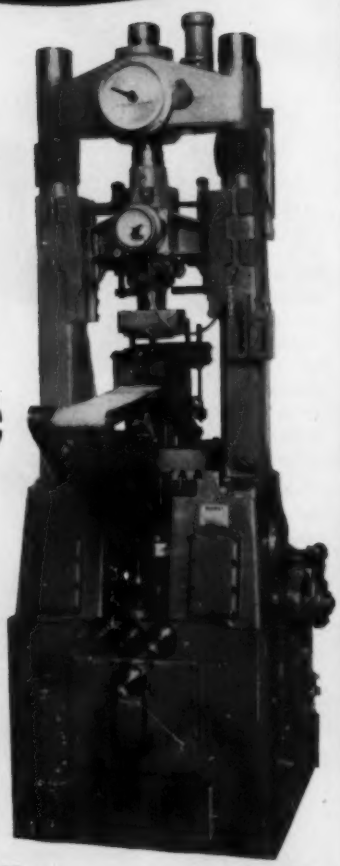

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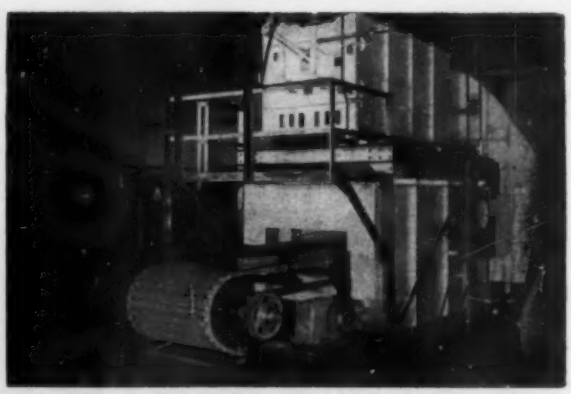

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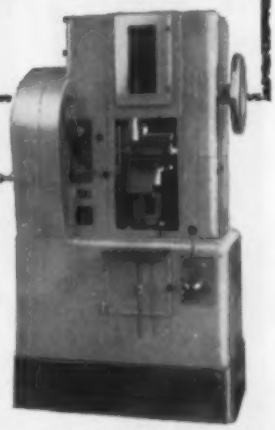

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Chemical Composition	Typical Composition: Tungsten Pellets	Typical Composition: Molybdenum Pellets
Tungsten, %	99.94	–
Molybdenum, %	0.050	99.85
Iron, %	0.003	0.010
Silicon Dioxide, %	0.003	0.020
Nickel, %	0.002	0.005
Aluminum, %	<0.001	0.005
Calcium, %	<0.001	0.050
Copper, %	<0.001	0.005
Magnesium, %	<0.001	0.050
Manganese, %	–	0.005
Chromium, %	–	0.001
Cobalt, %	–	<0.001
Lead, %	–	<0.001
Tin, %	–	<0.001
Density	14.0 g/cc	8.0 g/cc
Pellet Size	11/16" d x 3/8" h	11/16" d x 1/4" h

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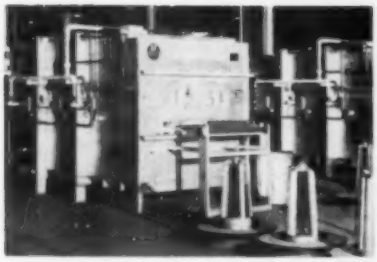
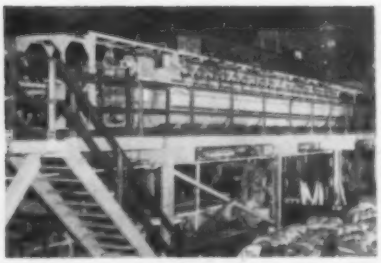
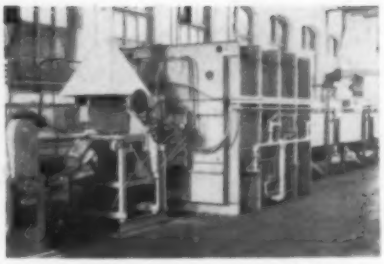


An EF multiple tube type furnace bright annealing stainless steel wire, continuously. One of an installation of five stainless steel furnaces we built in a prominent steel plant.



Large capacity EF gas fired furnace bright annealing stainless strip. We build them electrically heated or gas fired for wide or narrow strip, for single or multiple strands.



Stainless steel strip in various widths is bright annealed continuously in this EF gas fired special atmosphere installation equipped with an EF gas fired ammonia dissociator.

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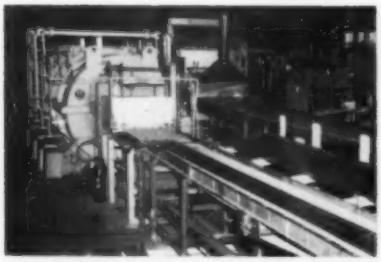
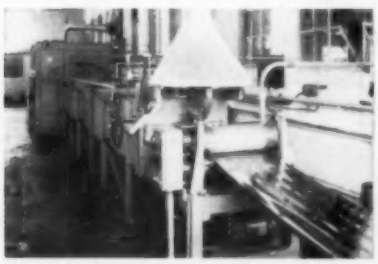


Stainless Steel Tubing in various diameters and lengths up to 24 feet is bright annealed continuously in this EF gas fired furnace.



Stainless Steel Strip. Wide, narrow and in various types, is uniformly bright annealed, continuously, in EF furnaces — any tonnage.

Stainless steel strip, wire, heavy and fine tubing, stampings, flatware, cooking ware, drawn and other stainless steel products, in many shapes and forms, are being bright annealed, uniformly, economically, continuously and with laboratory precision in EF furnaces of various sizes and types we have built.

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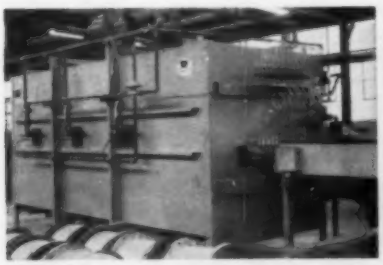
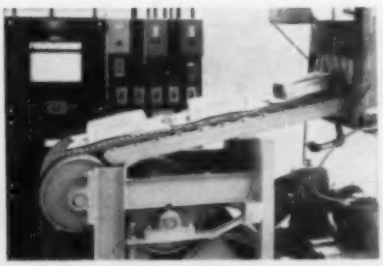
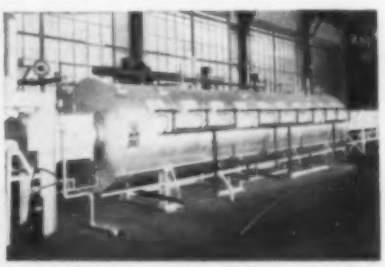


Stainless Steel Wire is bright annealed in this and other EF continuous and batch type gas fired and electric furnaces we build.



Stainless Steel Stampings, flatware, drawn and other products; large, small and in various shapes are bright annealed in EF furnaces.



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